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THE CONSEQUENCES OF NUCLEAR WAR ON THE GLOBAL ENVIRONMENT

REPORT

BY THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

together with

MINORITY AND DISSENTING VIEWS

AUGUST 3, 1983.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

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LETTER OF SUBMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C., August 3, 1983.

Hon. THOMAS P. O'NEILL, Jr.,
The Speaker, House of Representatives,
Washington, D.C.

DEAR MR. SPEAKER: By direction of the Committee on Science and Technology, I submit herewith the Committee's report to the 98th Congress. The Committee's report is based on an investigative study made by its Subcommittee on Investigations and Oversight.

Sincerely,

DON FUQUA, *Chairman.*

LETTER OF TRANSMITTAL

House of Representatives,
Committee on Science and Technology,
Washington, D.C., December 17, 1982.

Hon. Don Fuqua,
Chairman, Committee on Science and Technology, House of Representatives, Washington, D.C.

Dear Mr. Chairman: I am pleased to submit a report of the hearing which the Investigations and Oversight Subcommittee held on September 15, 1982, on the global environmental consequences of nuclear war.

We all recognize that countless millions will immediately perish in a nuclear war. However, until recently, few considered the longer term effects of a nuclear war on the Earth's environment. As to the latter, the Subcommittee sought to address the question of what the Earth would be like after a nuclear war.

In preparing for the hearing, the Subcommittee sought to obtain the widest possible range of opinions on the question of what Earth would be like after a nuclear war. Notwithstanding repeated efforts, the Subcommittee was unsuccessful in obtaining from the military or from any component of the military contractor community testimony on the post-war state of the Earth or on related issues such as the type and aggregate yield of weaponry that might be used in a nuclear war.

The testimony received at the hearing was both revealing and numbing. Noted scientists and physicians described a harsh and severe post-war world. In this world, 20–30 percent of the war's survivors could succumb to disease. Others would face the possibility of crop-killing sun blockage, intense pollution and blinding levels of ultra violet radiation.

Since the hearing, an article by Stanford physicist Edward Teller has been brought to the attention of the Subcommittee. Dr. Teller's article takes issue with some of the post-war ecological effects described at the hearing. The Subcommittee has appended to the report Dr. Teller's article in order to supplement the record. A reply to the Teller article by Dr. Frank von Hippel, who testified at the hearing, was published in the March 1983 issue of The Bulletin of the Atomic Scientists.

Because so much of what is known about the longer term effect of nuclear war is very new, more research is required. However, unlike the past where data on this subject was acquired by chance, a concerted and well-orchestrated research effort is required. This effort should be international in scope and should include Soviet participation.

I would like to extend thanks to Mr. Jerome Ostrov, on assignment to the Subcommittee on Investigations and Oversight, who helped organize the hearing and who assisted the Subcommittee in the preparation of the report.

Sincerely,

Albert Gore, Jr.,
Chairman, Subcommittee on Investigations and Oversight.

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Mr. FUQUA, from the Committee on Science and Technology, submitted the following

REPORT

I. INTRODUCTION

Thirty-seven years ago, a nuclear device packing the yield of 12,500 tons of TNT was detonated 1,900 feet above Hiroshima, Japan, with unprecedented casualties. Today, the device detonated over Hiroshima would equal about one-half of the area destrutive force of the smallest warhead on a U.S. nuclear re-entry vehicle. Yet, notwithstanding the unimaginable damage that lies within the capability of modern day weapons, the nuclear arsenals of both the U.S. and Soviet Union continue to grow.

Were a war to be launched using modern weaponry, the death toll would defy all comprehension. Even the most optimistic estimates project that between two and twenty million people in the United States would die as a result of a attack targeted solely on U.S. missile fields.

In spite of the unprecedented carnage embodied in such casualty projections, the Subcommittee had received reports and had heard of studies suggesting that the immediate death toll from a nuclear war would only represent the first of a series of health and ecological shocks that would jolt the planet and its survivors. Accordingly, on September 15, 1982, the Subcommittee held a hearing on the effects of nuclear war on the global environment. Testimony on both the mid-term health consequences as well the longer term atmospheric and ecological consequences of nuclear war was taken at the hearing.

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II. BACKGROUND

A. Issues considered by the subcommittee

1. Apart from the immediate death toll that would follow a nuclear war, what are the health and ecological risks that would confront mankind after such a war?

2. Are there any civil defense measures capable of dealing with the post-war health and ecological risks of nuclear war?

3. Is it likely that the damage inflicted on the environment by a nuclear war will render moot the question of who won or lost the war?

4. Has there been an orderly, well-conducted examination of the post-war health and ecological risks of nuclear war?

5. Are there scientific uncertainties that still remain?

B. Reason for the hearing

1. Predicted death toll from a nuclear exchange

In 1974, Secretary of Defense Schlesinger testified that, in the event of a counterforce (i.e., anti-military attack against the United States, there would be casualties in the range of 15,000 to 25,000 people.[1] Secretary Schlesinger later revised this estimate to 800,000 casualties.[2] Subsequently, the assumptions built into the Secretary's estimates were evaluated by an Office of Technology Assessment (OTA) expert panel. When changes were made in response to the OTA study, the official Defense Department projections ranged up to 20 million killed.[3]

Since the time of Secretary Schlesinger's statement and the upwardly spiraling casualty reassessments that followed his remarks, others have attempted to gauge the numbers of casualties that would perish in a nuclear war. Thus, in 1979, the Office of Technology Assessment, utilizing a January 1978 Congressional Budget Office nuclear force posture for both the U.S. and Soviet Union (see Appendix 1), provided casualty estimates for both a counterforce and full scale nuclear war.[4] Depending on the type of attack pattern used by the enemy (e.g., the season and accompanying wind patterns in which an attack would take place, the number of weapons that would be directed at a given target and whether those weapons would be air burst or ground burst), OTA estimated that between 2 and 20 million Americans would perish in a counterforce attack against U.S. military targets, in particular, the nine ICBM fields that are located in the western half of the nation.[5]

Were the attack to include other targets such as non-nuclear installations, petroleum fields and refineries, industrial installations and population centers, the number of Americans killed could be as high as 155 to 165 million people, or approximately 70 percent of the U.S. population.[6]

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[1] Hearings before the Subcommittee on Arms Control, International Law and Organization of the Senate Committee on Foreign Regulations, March 4, 1974 at p. 19.

[2] Statement of Frank Von Hippel before the Subcommittee on Investigations and Oversight of the House Committee on Science and Technology (hereafter the "Nuclear Aftermath" hearings), September 15, 1982, referring to September 11, 1974, hearings of the Subcommittee on Arms Control, International Law and Organization of the Senate Committee on Foreign Relations (hereafter the "Senate Arms Control Subcommittee) at p. 113.

[3] Statement of Frank Von Hippel supra note 2, citing "Analyses of Effects of Limited Nuclear Warfare," committee print, Senate Arms Control Subcommittee, September 1975, at p. 23.

[4] See OTA study, "The Effects of Nuclear War" (1979).

[5] "The Effects of Nuclear War" at p. 82.

More recently, in a study sponsored by the Swedish Academy of Science and published in Ambio, the Academy's bi-monthly international journal, noted scientists and strategists working in the nuclear arms arena were asked to evaluate the potential worldwide consequences of a nuclear war reference scenario provided by the magazine's authors and a distinguished board of advisors.[7] In the reference scenario, the Ambio board of advisors assumed that, by 1985, (i) the U.S. and Soviet Union would possess approximately 35,000 tactical nuclear warheads comprising about 4,400 megatons,[8] (ii) the U.S. would have at its disposal 12,840 strategic warheads with a total explosive power of about 3,510 megatons, and (iii) the Soviet Union would possess about 11,310 strategic warheads with an explosive power of about 4,140 megatons.[9] The Ambio advisory board then hypothesized that about one-third of the available warheads comprising less than one-half of the available megatonage would be used in a nuclear war.[10] Appendix 2 depicts the manner in which the Ambio advisory panel assumed that the weapons would be targeted.

Under the Ambio scenario, virtually every city in Western Europe, the United States, Canada, the U.S.S.R., Eastern Europe, parts of China and in other countries possessing nuclear weapons would be targeted.[11] When all such areas are included in the projected casualty estimate, the results are staggering: Out of an estimated population at risk of 1,290 million people, the use of weapons comprising less than half of the projected 1985 arsenals of the U.S. and the U.S.S.R. would leave 750 million dead and about 340 million seriously injured.[12]

2. *The importance of investigating the longer term consequences of nuclear war*

The Subcommittee felt it imperative to take its inquiry beyond the immediate carnage that would be wrought by a nuclear war and to look into the longer term health and ecological consequences of such a war.

The Subcommittee believed that such an inquiry was important for the following reasons: First, even under the most severe projections, it is expected that, after the last bomb has been dropped and the radioactive dust has settled, there will be survivors in each the Northern and Southern Hemisphere. Though most such survivors will be in the southern half of the globe, it can be expected that many will be in the northern half including upwards of 70 million

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[6] *Id.* at 95.

[7] See Ambio, volume XI, number 2-3, 1982, at p. 99 for a listing of those who contributed to the reference scenario.

[8] One megaton equals 1,000 kilotons of explosive power. One kiloton equals the explosive power of 1,000 tons of TNT. It is estimated that, in World War II, all of the weapons used possessed between 3-4 megatons of destructive capability. The bomb dropped on Hiroshima packed approximately 12½ kilotons of fire power, or about one-eightieth (1/80) of a modern day one-megaton warhead.

[9] See Ambio, note 7 *supra* at p. 94.

[10] The exact number of warheads and megatonage assumed comprised 14,737 warheads and 5,750 megatons. *Id.*

[11] *Id* at 95-96.

[12] H. Middleton, "Epidemiology: The Future Is Sickness and Death," *Id.*, Ambio at 102.

Americans. As to all such survivors, the Subcommittee felt it important to evaluate the type of world with which they would be confronted. Specifically, the Subcommittee thought it crucial to question whether the destructive forces unleashed by a nuclear war could wreak havoc not only on mankind but also on the environment in which mankind exists. Might it be the terrifying case that, for the survivors, the ability to continue life in an orderly fashion will become a fleeting illusion and that, in place of an organized society as we now know it, mankind will be relegated to foraging for food and protecting itself from unprecedented environmental, health and atmospheric adversities? If, as some have claimed, this is the setting that awaits the survivors of a nuclear war, the Subcommittee felt that all should know what nuclear war bodes for the future of mankind.

Second, at a time when the public debate over arms policy and disarmament is becoming more widespread than it ever has before, there is still a tendency on the part of many to shy away from the debate. The Subcommittee believes the reasons for this are twofold: For many, the thought of nuclear war is too unimaginable to contemplate. Therefore, there is the tendency to withdraw from the fray and take solace in the view that no national leader on either side of the globe could ever believe that a nuclear war is winnable and, therefore, startable. The other side of the coin for most each individuals is the tendancy to hope that were such a war started, they would be among the survivors.

It was with a view toward such individuals that the Subcommittee believed it important to discuss in a public forum what the Earth might be like after a nuclear attack. If, as some have claimed, the very atmosphere that surrounds us could be damaged allowing blinding rays to penetrate to the Earth; if, all of a sudden, the production of crops were to cease as a result of sun screening particles obscuring sunlight; and, if diseases, not known in the developed world for decades, were to return at epidemic levels, then, to paraphrase an oft-stated phrase, the living might envy the dead. With such knowledge in hand—grisly as it might be—the Subcommittee hoped that such American would assess what his or her role should be in helping to formulate a national arms and disarmament policy.

The third reason for the hearing was to provide a record for the leaders of both the U.S. and Soviet Union. If, as had been claimed, a nuclear war could not be waged without (a) sacrificing scores of millions of citizens and (b) risking the long-term ecological well being of the planet, then such leaders ought to be confronted with the facts in a way that clearly portrays the question of whether a nuclear war can be "won."

III. SUMMARY OF FINDINGS AND RECOMMENDATIONS

Findings

1. Issue.—Apart from the immediate death toll that would follow a nuclear war, what are the health and ecological risks that would confront mankind after such a war?

Findings.—Large-scale nuclear war poses a number of post-war medical and ecological risks. Among these are the possibilities of (i) radiation levels capable of killing or debilitating civilian populations located scores of miles downwind from an attack; (ii) post-war epidemics that could kill 20–30 percent of a war's survivors; (iii) sun screening caused by the dust from widespread forest fires and capable of blocking enough sunlight to inhibit photosynthesis in plants; (iv) smog in amounts sufficient to imapir food crops and pose health risks; and (v) depletion of the stratospheric ozone layer in amounts potentially capable of allowing blinding levels of ultra violent radiation to reach the Earth.

2. Issue.—Are there any civil defense measures capable of dealing with the post-war health and ecological risks of nuclear war?

Findings.—No civil defense measure brought to the attention of the Subcommittee will afford significant protection against the post-war health and ecological consequences of nuclear war.

3. Issue.—Is it likely that the damage inflicted on the environment by a large-scale nuclear war will render moot the question of who won or lost the war?

Findings.—Yes. Aside from the death toll, areas made uninhabitable by radiation and destruction of military, petrochemical, and industrial targets, large-scale nuclear war could wreak havoc with mankind's environment. Accordingly, whether or not a combatting nation can claim military victory, the cost of such "victory" may well be the loss of a sustainable environment.

4. *Issue.*—Has there been an orderly, well-coordinated examination of the post-war health and ecological risks of nuclear war?

Findings.—No. Much of what is known today is the product of isolated discoveries of interested scientists coupled with the recording of chance happenings.

5. *Issue.*—Are there scientific uncertainties that still remain?

Findings.—Many questions remain to be answered, in particular, questions involving the relationship between nuclear explosions and atmospheric chemistry, the potential for climate alteration and the relationship between ozone depletion and blindness.

Recommendations

Rather than allow the nuclear aftermath issue to be directed by chance happenings and isolated discoveries, the Subcommittee believes that a world-wide coordinated effort, akin to that of the 1957 International Geophysical Year, must be mounted and that researchers round the world must dedicate themselves to exploring the global consequences of nuclear war. To this end, the Subcommittee calls for an international year of research, and is pleased to note that three major research efforts aimed at investigating the global effects of nuclear war are now being explored by different components of the international scientific community. One of these, the planned Conference on Long Term Worldwide Biological Consequences of Nuclear War, is well under way with a major international conference planned for the early Fall of 1983.

To provide a forum for disseminating the findings and conclusions reached by the scientific conferences that are now getting underway as well as any that may be initiated in the near future, the Subcommittee recommends that a comprehensive set of hearings at the conclusion of the international year of effort be held.

Finally, to impart the findings of the scientific community to the leaders and people of both the U.S. and the Soviet Union, the Subcommittee can think of no better precedent than the recent televised meeting of U.S. and Soviet physicians[13] who, in a program that was broadcast live to the Soviet Union and later shown in the United States on public television,[14] candidly discussed the abhorrent medical nuclear war. The Subcommittee believes that no lesser treatment should be accorded the findings that flow from the international year of effort is as called for and urges the media of both the United States and the U.S.S.R. to consider such a live broadcast when the year's scientific activities have been concluded.

IV. EXPLANATION OF FINDINGS AND RECOMMENDATIONS

1. Issue.—Apart from the immediate death toll that would follow a nuclear war, what are the health and ecological risks that would confront mankind after such a war?

Findings.—Large-scale nuclear war poses a number of post-war medical and ecological risks. Among these are the possibilities of (i) radiation levels capable of killing or debilitating civilian populations located scores of miles downwind from an attack; (ii) post-war epidemics that could kill 20–30 percent of a war's survivors; (iii) sun screening caused by the dust from widespread forest fires and capable of blocking enough sunlight to inhibit photosynthesis in plants; (iv) smog in amounts sufficient to impair food crops and pose health risks; and (v) depletion of the stratospheric ozone layer in amounts potentially capable of allowing blinding levels of ultra violet radiation to reach the Earth.

A. Radiation effects

In addition to the blast and thermal effects of a thermal nuclear explosion, a nuclear bomb dissipates about 10% of its energy in the form of nuclear radiation.[15]

In the case of a single nuclear weapon with a yield of one megaton, a ground blast attack utilizing such a weapon could spread radiation of 500 to 1000 rems[16] over an area approximating 1000 square miles.[17] To appreciate the intensity of such radiation, one need only consider that the dose levels that will likely cause fatalities in the case of 50 percent of those who are exposed is thought to be 450 rems.[18] Further, amounts less than 450 rads could cause death or debilitating injury, depending on the dose. For example,

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[13] Participating in this historic televised meeting were Drs. Bernard Lown and John Muller of the Harvard Medical School; Dr. John Pastore of the Tufts University Medical Center; Dr. Evgueni Chazov, U.S.S.R. Deputy Minister of Health; Dr. Mikhail Kuzin, Director of the Soviet Surgical Institute, and Dr. Mikhail Ilyin, Director of the U.S.S.R. Byophysics Institute.

[14] The rebroadcast was aired in the United States on October 13, 1982, under the title "Nuclear War: Incredible Disease."

[15] Statement of Dr. Arthur Westing (p. 2) at the Nuclear Aftermath hearing.

[16] Hereafter, the terms rad and rem will be used interchangeably. Both refer to radiation energy absorbed.

[17] Testimony of Dr. Sidney Drell at Nuclear Aftermath hearing at transcript 181 (regarding area of impact). See also B. Feld, Mechanics of Radiation, "The Final Epidemic" at p. 114 (regarding the intensity of impact). "The Final Epidemic" was brought to the attention of the Subcommittee by the Physicians for Social Responsibility from whose membership two witnesses, Dr. J. Jack Geiger and Dr. Herbert L. Abrams, testified.

[18] "Effects of Nuclear War" at p. 110.

100 rems may well produce cataracts which, if untreated, could lead to blindness.[19]

Though the fallout intensity from the cigar-shaped radiation plume will decrease as one moves more than 50 miles down the axis of the radiation plume,[20] it has, nevertheless, been estimated that lethal doses of radiation from a one megaton burst would cover an area approximately thirteen miles wide and ninety miles long.[21] Others have estimated that the lethality range could extend for more than 160 miles downwind with a width of about 25 miles.[22]

Operating from the assumed force posture depicted in Appendix 1, ACDA (the Arms Control and Disarmament Agency) has attempted to depict the effects of radiation from a full scale attack on the United States. ACDA's map depicting the estimated fallout pattern of dose levels exceeding 1000 rems appears as Appendix 3. As can be seen, the area blankets the Northeast, Midwest, Central U.S. and most of California. Within these areas, even people who remained indoors, such as in frame houses, would receive potentially lethal exposures of 300–500 rems.[23]

While the above estimates are based on the radiation patterns produced by large, i.e., one megaton, ICBM's, one should not assume that only such weapons can produce extraordinarily harsh radiation effects. In a recent study which assumed (a) a "limited" nuclear encounter in East and West Germany, and (b) the use of tactical nuclear weapons averaging 200 kilotons, it was postulated that between 2 and 20 million people would perish.[24] Appendix 4, which is the conception of three scientists active in the nuclear war field and which does not necessarily reflect the agreement of other scientists and strategists who have thought about the problem, depicts (a) the population density of the two Germanies and (b) the predicted fallout from a preemptive attack on military targets in East and West Germany using 200 kiloton weapons. The Appendix suggests that much of the destruction would be due to radiation exposure.

Finally, were nuclear weapons targeted on nuclear power plants, the radiation effects described in the above discussions could be markedly worsened. It has been estimated that the long-life fission products in one nuclear reactor are equivalent to the radiation product of 40 megatons of nuclear weaponry.[25] Hypothetically, if an attack pattern encompassed the approximately 150 nuclear reactors in the world, the destruction of these reactors could add the equivalent in long life fission products of 6000 megatons of weaponry.[26] Obviously, one cannot anticipate with any degree of assurance that all of the world's widely dispersed nuclear reactors would be included in any given attack scenario. As a hypothetical frame of reference, Appendix 6 depicts *Ambio's* conception of the worldwide radiation effects, in amounts exceeding 100 rads, of an attack scenario which targeted these reactors.

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[19] Testimony of Herbert Abrams, M.D., at the Nuclear Aftermath hearing at transcript 1907.

[20] "The Effects of Nuclear War", at p. 84.

[21] See Ambio, note 7 *supra* at p. 97.

[22] "The Economist, May 15, 1982, at p. 96.

[23] "The Effects of Nuclear War" at p. 21.

[24] W. Arkin, F. Von Hippel, B. Levi, "The Consequences of a Limited Nuclear War in East and West German," Ambio, note 7 *supra* at p. 170.

[25] Testimony of Frank Von Hippel at Nuclear Aftermath hearing at transcript 3754. Hereafter, transcript references apply to the yet unprinted stenographer's transcript. Statements refer to the written statements of the witnesses.

[26] *Id.* at transcript 3762.

B. Health effects

For those who are exposed to lethal doses of radiation, death will come within weeks of exposure. For those who receive lesser doses, the threat of cancer will exist as a menace for the rest of their lives. It has been estimated that, as a result of the nuclear tests conducted before such testing was banned in 1962, there have been an additional 100,000 deaths from cancer worldwide.[27] These tests, numbering 1,270, would account for only a fraction of the potential detonation in a nuclear war. Further, evidence of high cancer incidence among survivors of Hiroshima and Nagasaki continues to mount,[28] with data indicating that the risk to exposed infants and fetuses *in utero* being ten times greater than the risk to adults.[29] For this latter category, the incidence of cancer could be as great as 100 cancers per 1,000.[30] In total, assuming a war scenario such as that hypothesized by *Ambio,* 5.4 million out of the 200 million Northern Hemisphere survivors could expect to die from cancer.[31]

Apart from the projected cancer death toll due to radiation exposure, perhaps the most serious radiation-induced problem confronting survivors will be that of vulnerability to disease. Radiation exposure decreases antibody response to disease and decreases the effectiveness of cellular defense mechanisms.[32] The increased susceptibility, which can last for months after an attack,[33] will be compounded by other factors such as trauma, exposure, burn and hardship.[34] Accordingly, unless one is completely removed from the fallout patterns that will engulf most of the United States, susceptibility to disease will be a major issue for those who survive the initial attack. For as many as 20 to 30 percent[35] of those who do survive, disease could be determinative and eventually lead to death. The reasons for this are several fold.

First, whether or not one is in a shelter, all but the luckiest of survivors will require some medical attention. Yet, for such persons, help is likely to be unavailable or extremely scarce. Hospitals will have been destroyed, roads and transportation corridors will have been disrupted or destroyed, gasoline required for those vehicles that are able to travel will be scarce and an estimated 80 percent of the physicians and nurses in the attack zone will have been killed. In one Nagasaki hospital, 892 out of 1100 doctors and nurses perished[36] from a single nuclear explosion of less than 20 kilotons. By contrast, most full-scale war scenarios such OTA's "The Effects of Nuclear War" and the Ambio study assume that any city of consequence would be targeted with at least one megaton, i.e., 1000 kilotons, of weaponry.

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[27] Testimony of Herbert Abrams, note 19 *supra* at transcript 1465.

[28] *Id.* at transcript 1478.

[29] Statement of H. Jack Geiger, M.D., (p. 4) at Nuclear Aftermath hearing.

[30] *Id.*

[31] *Id.* at p. 5.

[32] Testimony of Herbert Abrams, note 19 *supra* at transcript 1164.

[33] Id. at transcript 1181.

[34] Id. at transcript 1164.

[35] Id. at transcript 1429. The death rate due to disease could even be higher as suggested by a computer simulation of a nuclear blast nine miles outside of New Orleans. In the simulation, fully 35 percent of the survivors were found to die from infectious disease.

[36] PBS Inside Story, "Nuclear War: The Incurable Disease."

In such a setting, those survivors not felled by radiation exposure and able to find shelter would experience oppressively tight crowding in surroundings punctuated by illness and death. For days or weeks, radiation levels would prevent activity outside of the shelter. Unless food and water had been stored away in ample supplies, malnutrition and hehydration would soon occur. Infections among those in shelter areas would be passed on to others and the presence of corpses would lead to more disease.

Rats and insects are major carriers of disease. Because their natural habitat is in subterranean areas such as basements, the rat population would tolerate radiation effects relatively more effectively than humans.[37] Insects would tolerate radiation levels better than humans because of a natively higher resistance to radiation.[38] Together, these pests would account for the reintroduction into the war-torn areas of such previously vanquished diseases as plague.[39] Diseases such as typhus and malaria would also run rampant.[40]

History has demonstrated a strong correlation between protein intake and tuberculosis.[41] Particularly during war time when food shortages have existed, the incidence of tuberculosis has always increased.[42] After a nuclear attack, food shortages in areas hit by the attack will lead to high incidences of TB. Further, even after radiation levels have dissipated to the point where foraging is possible, contamination will have made most food stuffs inedible. Whether scarce fuel supplies and destroyed transportation corridors will allow food and water to be brought in will become an acute dilemma particularly since the Nation's food centers tend to be located away from its population centers. However, as will be discussed,[43] whether such food supplies will, in any event, be available after a nuclear war is, itself, a problematic matter.

C. Sun screening

For a number of years, scientists have speculated as to the climatic and other atmospheric effects of multiple detonations of nuclear weapons. In particular, there has been concern with the weather modification potential of widespread nuclear blasts that could pulverize target areas into dust and cause such dust to be thrown aloft in much of the same way that volcanic dust is projected high into the air.[44] However, in 1975, the National Academy of Sciences, in a study entitled, "Long-Term Worldwide Effects of

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[37] Testimony of Herbert Abrams, note 19 *supra* at transcript 1395.

[38] *Id.* at transcript 1293.

[39] *Id.* at transcript 1374.

[40] *Id.* at transcript 1293.

[41] *Id.* at transcript 1426.

[42] *Id.* at transcript 1424.

[43] See later discussions involving affect of sun screening and smog on plant production.

[44] Through discussions with representatives of the Defense community, Subcommittee staff learned that the Department of Defense had an interest—though had taken no position—on the subject of war-induced airborne dust and weather modification. Accordingly, the Department of Defense was invited to testify on this subject as well as on any other relevant issue involving the atmospheric effects of nuclear war (see transcript at p. 146). Though DOD declined to testify, the DOD has since requested the National Academy of Science to investigate the ariborne dust issue as well as other atmospheric issues related to nuclear war.

Multiple Nuclear-Weapons Detonations" (hereafter "the 1975 NAS study"), expressed only mild concern at the temperature modification potential of blast-induced atmospheric dust. Assuming that a full scale nuclear war would utilize 10,000 megatons of weaponry, the Academy concluded that the amount of dust injected into the air would be 10^7–10^8 tons—an amount though to be of the same order as that caused by the eruption of the South Pacific volcano, Krakatoa, in the year 1882. As with Krakatoa, the Academy estimated that the temperature effects of large scale nuclear war would amount to a reduction in global surface temperatures of a few tenths of a degree centigrade over a one to three year period.[45] However, the Academy cautioned that the possibility of temperature changes of a greater magnitude "cannot be ruled out."[46]

Subsequent to the Academy's 1975 study, it was not until 1982 that researchers from the University of Colorado and the Max Planck Institute for Chemistry (Mainz, Germany) hypothesized an entirely different and potentially much more disastrous dust phenomenon than that originally envisaged by the Academy. Specifically, utilizing the *Ambio* attack scenario previously discussed, these researchers foresaw that detonation of the 14737 [47] tactical and strategic warheads assumed by the scenario would set ablaze more than one million square kilometers of forest lands in the Northern Hemisphere. At the Subcommittee's hearing, Dr. John Birks, one of the study's authors, testified that the figure in question was probably an underestimate. In part, his conclusion was based on an early U.S. Forest Service estimate that, in the event of a 1,500 megaton attack on the U.S.—a figure which is a little more than one-fourth of the total megatonage assumed in the Ambio scenario, between 400 thousand and 6 million square kilometers of forest lands would be lost to fire.[48]

Based on their million square kilometer estimate, Birks and his co-researcher, Dr. Paul J. Crutzen, concluded that between 200–400 million tons of particulate matter dust would be released into the atmosphere from the uncontrolled forest infernos. Further, assuming that the forest fires would last for two months, the researchers concluded that the fires would cause average particle dust loading in the atmosphere equal to 0.1 to 0.5 grams per square meter. In consequence, the amount of sunlight reaching the Earth could be reduced by a factor of between 2 and 150 at noontime in the summer, and could be even larger during other times of the year. In short, stated the study authors, "it is quite possible that for several weeks following a nuclear war more than 99 percent of the sunlight would be blocked for much of the Northern Hemisphere." (Statement at page 3.) Moreover, cataclysmic as these conclusions might be, they do not take into account potential particulate dust contributions from long burning Arctic peat bog or from combustion in cities, industrial centers and oil and gas wells. Were fires from cities and in oil and gas fields taken into account, the authors of the study suggest that the sun screening effects postulated above could even be worse. This is because fires of this variety would be very hot causing the heated particulate dust to rise high into the atmosphere were its sun screening potential would be greatly prolonged.

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[45] 1975 NAS Study at p. 6.

[46] *Id.*

[47] See Appendix 2 *infra* which reflects this figure.

[48] Testimony of John W. Birks at the Nuclear Aftermath hearing at transcript at 2371.

D. Photochemical smog formation

As most high school chemistry students know, when materials such as wood, oil, and gas are combusted, a number of combustion byproducts are formed. Among these are nitrogen oxides, carbon monoxide and reactive hydrocarbons such as ethylene and propylene. When subjected to sunlight, these chemicals combine in a photochemical reaction to produce photochemical oxidants of which ozone is a major variety. At low enough elevations, ozone, or, smog, as it is commonly referred to, is a familiar and, at times threatening pollutant. The U.S. Environmental Protection Agency has established a maximum exposure of 120 parts ozone per billion as the national ambient air quality standard for ozone.[49] The standard is satisfied when no more than one day per calendar year is expected to experience maximum hourly ozone concentrations above the 120 parts per billion requirement.[50]

Great amounts of nitrogen oxides are released from the detonation of nuclear weapons. In the case of a war utilizing 5,742 megatons of weaponry, i.e., the Ambio scenario, it is estimated that such multiple explosions would introduce about 13.4 million tons of nitrogen oxides into the atmosphere.[51] Assuming that the blasts would set off forest fires in the manner previously suggested and that a significant number of weapons were targeted at the world's oil and gas fields,[52] Birks and Crutzen estimate that an additional 15-30 million tons of nitrogen oxides[53] could be released into the atmosphere. They further estimate that, added to the nitrogen oxide combustion products would be 200–400 million tons of carbon monoxide and tens of millions of tons of reactive hydrocarbons.[54] What these men see as the effect of these chemical releases is that, once the fire-induced, sun-screening particles settle back to the Earth and sunlight begins to reappear, the Northern Hemisphere might well be buffeted by, yet, a second atomospheric shock. The shock would take the form of layer of densely polluted ozone smog. As compared to the 30 parts per billion average ozone content normally found in the Northern Hemisphere, the ozone content that they foresee would average 160 parts per billion[55]—33 percent greater than EPA's one day per year standard—and would likely exceed this figure over land masses. The two authors caution that unforeseeable chemical interactions could occur, such as the possibility that smoke particles might take up, i.e., absorb, some fraction of the oxides of nitrogen thereby tending to cleanse the air. Nevertheless, they also note that their calculations do not include such negative variables as the combustion effects of the many fires that would blaze uncontrollably in cities.[56] Further, they state that what they have hypothesized may only be an example of what might occur as a result of nuclear war.

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[49] 40 C.F.R. § 50.9.

[50] *Id.*

[51] Statement of John W. Birks and Paul J. Crutzen (p. 4) at Nuclear Aftermath hearing.

[52] The Ambio scenario utilized by Birks and Crutzen assumed that oil and gas fields and much of the world's petrochemical installations would be targeted with nuclear weapons.

[53] Statement of John W. Birks and Paul J. Crutzen (p. 4), note 51 *supra*.

[54] *Id.*

[55] *Id.*

E. Destruction of the Earth's protective ozone layer

In 1975, when the NAS completed its study of the long term effects of nuclear war, one of the predicted phenomena it found to be most surprising[57] was the possibility that ozone in the Earth's stratosphere might be depleted by large pulses of oxides of nitrogen formed by the multiple detonation of nuclear weapons.

Because of the chemistry that exists in the Earth's stratosphere, oxides of nitrogen that are projected high enough into the air act to deplete or destroy stratospheric ozone. By contrast, as we have seen, nitrogen oxides may act to promote ozone at lower elevations such as in the troposphere. The differing effects are extremely important because, unlike the ozone which, at lower levels in the Earth's atmosphere acts as a pollutant, ozone in the upper atmosphere acts as a protective filter sheltering the Earth from what would otherwise be damaging levels of ultra violet radiation.

Utilizing an assumed war-time arsenal approximating 10,000 megatons of weaponry, the NAS concluded that "ozone reductions in the range of 30–70 percent are possible."[58] For the Southern Hemisphere, where less of the direct effects of a war would be felt, the NAS stated that ozone reduction might be "in the range of 20 to 40 percent." [59] Because of the significance of these conclusions, the Subcommittee invited Dr. James Friend, who was co-chairman of the Atmospherics Effects section of the 1975 NAS study, to testify before it. In particular, the Subcommittee was interested in other studies that may have been conducted since the Academy study and which used weapons assumptions that more closely corresponded to present day arsenals than the weapon yields that were employed by the Academy.[60]

Dr. Friend's testimony included the results of recent ozone depletion studies conducted by Dr. Julius Chang of the Lawrence Livermore National Laboratory. Dr. Chang was a member of the 1975 academy team which investigated the ozone depletion phenomenon, and has continued to do work in the field.

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[56] *Id.* at p. 5.

[57] In an August 12, 1975, cover letter transmitting the study to ACDA, then NAS President Philip Handler wrote:

"Perhaps surprisingly, outside the directly affected countries, the major predicted long term effects are thought to derive not from the dispersion of radionuclides but from an increase in the flux of ultraviolet radiation on the earth's surface due to reduction in the stratospheric consequence of ozone . . . Indeed, this is the principle new point developed in this report."

[58] 1975 NAS Study at p. 6.

[59] *Id.* Though all of the expert witnesses agreed that ozone depletion will be greater in the war-torn Northern Hemisphere than in the Southern Hemisphere, of importance is the fact that none believed that the Southern Hemisphere would be immune from such effects merely because it would escape most of the nuclear fighting.

[60] As noted that 1975 NAS study assumed total weaponry with an aggregate yield of 10,000 megatons. The 10,000 megaton figure approximates the most recent arsenal data made available to the Subcommittee. (See Appendix 6 which contains a Congressional Research Service (CRS) estimate of the nuclear arsenals of the U.S. and the Soviet Union at the end of 1983, assuming both adhere to the general guidelines of Salt I and Salt II.) However, the NAS did assume that, of such total megatonage, the mix of weapons would include some combination of 500 to 1000 weapons in the 10 to 20 megaton range and 4,000 to 5,000 weapons in the 1 to 2 megaton range. It is this mix with its heavy emphasis on the larger weapons that is not reflected in present day arsenals.

For his calculations, Dr. Chang utilized the force posture employed by OTA in its 1975 study on the effects of nuclear war (see Appendix 1). Based on the 13000 megatons of weaponry reflected in that force posture, Dr. Chang concluded that a war which employed such an arsenal would deplete the Earth's ozone layer by 63 percent. Among the significant aspects of this finding were the following three conclusions which were reported to the Subcommittee by Dr. Friend.

First, while Dr. Chang's depletion figures assume that all 13,000 megatons worth of weaponry would be detonated, much of the predicted 63 percent depletion level would probably be reached at a lower total yield. This is because the relationship between nitrogen oxide penetration and ozone depletion is not linear. Rather, as the nitrogen dioxide in the stratosphere approaches certain values, most of the potential damage to the ozone layer will have taken place, and additional amounts of nitrogen dioxide will create disproportionately small effects.[61] This can be illustrated by the following table[62] which reflects the "working curves" or depletion levels postulated by the 1975 NAS atmospheric effects working group:

Megatonage	Increase in nitrogen oxides (percent)	Ozone depletion (percent)
10,000	1,000	50
5,000	500	37
1,500	150	25

From the table it can be seen that, even where the assumed megatonage is reduced by a a factor of 6⅔ (10,000 to 1,500) the assumed ozone depletion goes down by only a factor of 2 (50 percent to 25 percent). Accordingly, while the 63 percent depletion value associated with the 1979 OTA force posture might not occur unless all 13,000 megatons worth of weaponry were detonated, a 50 percent, or even 60 percent, depletion factor might well occur at substantiallyi less than 10,000 megatons.[63]

Second, the size, i.e., yield in megatons of the weapons employed, is significant. For example, if only those weapons in the 500 kiloton or less category were detonated, the depletion factor would only be 5 percent. This is because such weapons do not produce enough thrust to launch the nitrogen-oxide-releasing nuclear fireball high enough into the air to penetrate the stratosphere. By contrast, if only those weapons equal to or exceeding 2 megatons in yield or more were detonated—a total which represents less than two percent of the warheads assumed in the 1979 OTA force posture, 23 percent of the postulated 63 percent depletion would occur.[64]

This last calculation is significant not only because of what it says with regard to the destructive force of existing high yield weapons and what the detonation of those weapons might mean to the Earth's environment, but also because of what it implies with respect to new weapons systems. The tendency, at least on the part of the United States, has been to design lower yield, more accurate weapons. Aside from the later-discussed possibility that even smaller weapons detonated in the same target zone could adversely affect the ozone layer, this trend is favorable from an atmospheric effects point of view. However, a sudden change of direction in the arms race could, in particular, prompt the Soviets to re-emphasize higher yield weapons such as their existing single warhead SS-18 and SS-19 ICM's.

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[61] Testimony of James P. Friend at the Nuclear Aftermath hearings at transcript 3648-56.

[62] Derived from statement of James P. Friend (p. 4) at the Nuclear Aftermath hearing.

[63] Testimony of James P. Friend, note 61 supra.

[64] *Id.* at transcript 2274.

For example, a pertinent November 5, 1982 New York Times article discussing the Administration's Dense Pack basing plan for the MX missile was recently brought to the attention of the Subcommittee. The article quotes Air Force Special Assistant for the MX, General Gordon E. Fornell, as saying:

> Changing the shape of the [MX basing] field from what was roughly a triangle to a slender line . . . would force the enemy to expend 10 megatons a minute in pindown explosions.
>
> When you start talking about 10 megatons a minute, you start exhausting [Soviet] resources and drive [them] to development of new warheads larger in yield.

What Dr. Chang's calculations show is that development of high yield weaponry, presumably of the variety noted above, poses not only the treat of massive destruction on the face of the Earth, but also the potential for incalculable damage to the Earth's ozone shield which protects Americans and Russians alike.

Dr. Chang's second conclusion cannot be construed as dismissing the ozone damaging potential of smaller yield weapons. For one thing, Dr. Chang did postulate a 40 percent ozone destruction potential utilizing weapons with yields of less than 2 megatons.[65] For another, scientists are not yet in agreement on how large a weapon yield is required to thrust the nuclear fireball high enough into the atmosphere to do damage. In particular, scientists at MIT have been evaluating the thermal buoyancy effect of detonating more than one weapon in the same place. According to the theory which they are investigating, the detonation of multiple "smaller" weapons in one place could cause what is referred to as a "tunneling" effect. Once created, the so-called tunnel enables the nuclear fireballs to be thrust higher into the air than would be true of just a single blast. According to very preliminary modeling results conveyed to the Subcommittee by Dr. Kosta Tsipis of MIT, as a result of tunneling, ozone depletion levels, thus far associated with high yield weapons, could occur even where smaller megaton weapons are used. Since most counterforce strategists assume that, in the event of war, two, or possilbly more, Russian warheads would be targeted at America's ground-based missiles, the multiple-weapon-per target scenario clearly bears considering. Accordingly, the Subcommittee has asked Dr. Tsipis to present his findings to the Subcommittee when they are completed.

Dr. Chang's third conclusion has to do with the time frame during which a depleted ozone layer would replenish itself. In this regard, Dr. Friend testified that it would take two years to recover half[66] of the depletion and four to five years to reach pre-existing ozone levels.[67] During this time frame, world-wide effects would be at their worst about six months after a war took place.[68]

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[65] *Id.*

The significance of the above is that, once the Earth's protective ozone layer is pierced and ultra violet radiation at enhanced levels is allowed to reach the surface of the Earth, the effects of such rays can be expected to last for years. As will be seen in the next section, the effects may well be severe.

F. The effects of the described atmospheric insults to the Earth

In sections C through E, the Subcommittee has discussed the possibility that large-scale nuclear war could so damage the Earth's atmosphere as to cause sun screening, intense smog and ozone depletion. The remarkable fact is that each of these insults could occur in sequence with mankind and all other forms of life experiencing the jolt of weeks of a blackened, sunless sky, followed by intense smog as the sunlight reappears, followed by potentially blinding ultra violet rays as the depletion of the ozone layer reaches its worst phase six months after the beginning of a large-scale nuclear war.

Most significantly, one must consider the long term consequences of sun screening and its implications for the future of those who have survived. For example, will crops grow in such an environment? Can the plankton that serve as the lynch pin of the oceanic food chain survive? The Subcommittee was told that the sun screening caused by massive war-induced forest fires could be so grave as to inhibit photosynthesis among food crops. Particularly, if a war were waged during the summer growing season, the effects of sun screening would be such that most of the crops in the Northern Hemisphere would die and that significant yields of food crops during the year following a large-scale nuclear war would be unlikely. In addition to Northern Hemisphere effects, the above circumstances would also place in grave danger those other people of the world who have come to rely upon staples from the North American heartland. For such people, the effect of a year-long North American crop drought would only add to the burden of having to forego all of the other advances of what had been the developed half of the globe.

Should smog levels occur on the order predicted by Birks and Crutzen, the polluted environment can be expected to aggravate the already weakened condition of many survivors and cause respiratory illness, nausea and headaches.[69] In addition the Subcommittee was advised of studies conducted by the U.S. EPA in which crops exposed to maximum ozone levels of 100 parts per billion for seven hours per day during the course of their growing season showed markedly reduced yields. Extrapolated to the post-war 160 parts per billion, 24 hour average ozone values predicted by Birks and Crutzen, these EPA studies suggest the possibility of greatly diminished post-war crop yields even in the absence of sun screening.[70] This, of course, assumes that a war were fought in the summer months.

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[66] *Id.* at transcript 2926.

[67] *Id.* at transcript 2930.

[68] *Id.* at transcript 2900.

[69] Response to John Birks to supplemental question 2 posited by the subcommittee following the Nuclear Aftermath hearing.

Whatever the season, however, it may be that the potentially most severe atmospheric effect will not occur until several months have elapsed following a nuclear war. The effect in question is that of harmful ultra violet rays penetrating through the Earth's depleted ozone layer and reaching peak destructive intensity about six months after a nuclear war.

As previously mentioned, ozone in the stratosphere serves to filter what would otherwise be harmful ultra violet radiation from the sun. This filtration process shelters the Earth from radiation in the 200–288 nanometer range,[71] a phenomenon which is extremely important since at 270 nanometers, ultra violet (UV) radiation can split DNA molecules causing cellular destruction.[72]

The most serious consequence of enhanced levels of UV radiation at the 270 nanometer range is eye damage.[73] Assuming a 50 percent ozone depletion level—a possibility which, based upon the 1975 NAS study, the work of Dr. Chang[74] and the preliminary findings of Dr. Tsipis, appears to be within the destructive capability of current day arsenals—the Subcommittee was advised that ultra violet radiation would be so severe as to produce blindness after outdoor exposure periods as short as 30 minutes.[75] Moreover, if one additionally assumes that much of the Earth will be defoliated as a result of blasts and fire, the exposure period could be considerably less because UV which is normally absorbed by vegetation will be reflected off the Earth, further exposing one's eyes to the harmful UV radiation.[76] Indeed, it is possible that, at a 50 percent depletion level, the maximum safe exposure could be as little as 31 seconds.[77] This derives from the fact that at such depletion levels, the amount of UV reaching the Earth will be twice the threshold for safe exposure.[78] At such intensity, corneal damage can occur after a period as short as 31 seconds.[79] Unless medically treated, the corneal damage could lead to cataracts which are the major cause of blindness among humans.[80] Since, as previously pointed out, medical care and medicines will be in scarce supply, the prognosis for corneal-damaged survivors will be grim. Further, even if medical care were initially available, such care would soon be stretched thin since the exposure conditions and concomitant eye damage risk discussed above will exist as long as it takes for the Earth's ozone layer to replenish itself,[81] a period which could be expected to last for 18 months after its worst intensity was reached.

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[70] *Id.*

[71] Testimony of Dr. Donald Pitts at Nuclear Aftermath hearing at transcript 1686.

[72] *Id.* at transcript 1678.

[73] *Id.* at transcript 1736–45.

[74] With a view toward the relationship between ozone depletion and arsenal size, the Subcommittee has asked Dr. Chang to evaluate the ozone depletion potential for the nuclear arsenals predicted in CRS's end-of-1983 scenario. See Appendix 6. Due to a typographical error, the tables originally forwarded to Dr. Chang showed the Poseidon missile as having a yield of .4 megatons rather than its actual rated yield of .04 megatons. This error has been corrected in Appendix 6(b) and Dr. Chang has been asked to modify his conclusions to reflect the error. It should also be noted that the CRS estimate does not contain theater or tactical nuclear weapons. If used in a nuclear war. nitrogen oxide pulses from these weapons could be expected to add to the ozone depletion effects of the war.

[75] Testimony of Dr. Donald Pitts note 71 *supra* at transcript 1905.

[76] *Id.* at 1745, as augmented by later staff conversation with Dr. Pitts.

[77] *Id.* at transcript 1756.

[78] *Id.* at transcript 1769.

[79] *Id.*, as augmented by later staff conversations with Dr. Pitts.

[80] *Id.*

The Subcommittee was also advised that, as to potential eye damage, little solace can be derived from the possibility that a large-scale nuclear war would deplete the ozone layer by less than 50 percent. For example, at a 30-percent depletion level, UV exposure could still produce inflamation of the cornea of the eye.[82] This, in turn could lead to scarring of the eye tissue, reduction of vision, and if untreated within two to three weeks, possible blindness.[83] Further, even at depletion levels of 10 percent, many of the risks posed above would be present if UV in the active 260-290 nonometer band is able to reach the Earth.[84]

While the effects of UV exposure are insidious with the exposed individual not being aware of what is happening for 3 to 6 hours,[85] it can be expected that many humans will learn from experience and leave their quarters only at night or for short periods of time. Unfortunately, for animals, this will not be the case and many, if not most, will be felled by the enhanced UV levels.

Other sources of mankind's food supply will also feel the effects of enhanced ultraviolet radiation. One of the Subcommittee's witnesses estimated that 20 percent of the plant species on Earth, including crop plants, would become extinct due to levels of UV of the intensities described above.[86] In conversations with staff, another witness suggested that, at 30 percent ozone depletion, the UV allowed to penetrate to the Earth would kill many forms of vegetation.[87] Further, were marine plankton lieing close to the surface of the ocean killed by intense UV levels, the entire oceanic food chain would be in jeopardy and, with it, another source of mankind's food supply.[88]

Whether, as one witness concluded, the environmental effects discussed above will have a reinforcing influence on one another causing the whole to be much worse than its component parts,[89] is anyone's guess. However, taken by themselves, each of the effects would be cataclysmic by standard.

1. *Issue.*—Are there any civil defense measures capable of dealing with the post-war health and ecological risks of nuclear war?

Findings.—No civil defense measure brought to the attention of the Subcommittee will afford significant protection against the post-war health and ecological consequences of nuclear war.

Dire as the health and atmospheric effects described above may be, the Subcommittee felt it incumbent to raise the question whether civil defense measures could significantly mitigate the effects that could otherwise follow a nuclear war.[90]

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[81] Response of Dr. Donald Pitts to supplemental question 4 posited by the Subcommittee.

[82] Testimony of Dr. Donald Pitts note 71 *supra* at transcript 1969, as augmented by later staff conversation with Dr. Pitts.

[83] *Id.*

[84] Response of Dr. Donald Pitts to supplemental question 3 posited by the Subcommittee.

[85] Testimony of Dr. Donald Pitts note 71 *supra*. at transcript 1667.

[86] Testimony of Dr. Arthur Westing at Nuclear Aftermath hearing at transcript 2816.

[87] Staff conversation with Dr. Donald Pitts, citing NASA studies.

[88] Testimony of Dr. Arthur Westing note 86 *supra* at transcript 2803.

[89] See, for example, *Id.* at transcript 2858.

There are three major approaches to civil defense. The first is the deployment of anti-ballistic missile (ABM) systems. However, apart from the fact that deployment of such systems is severely limited under the ABM Treaty, the Subcommittee places considered stock in the testimony of Dr. Sidney Drell that there is "no prospect of deploying—on ground or in space—an effective defesnse of the nation's people and industry."[91]

The second approach to civil defense is that of sheltering the population at risk. Putting aside the question whether would-be shelter occupants will receive adequate warning of an attack, shelters could save lives. The number saved would, of course, depend on the construction of the shelters and their proximity to an attack. The question addressed by the Subcommittee was how well such shelter occupants would make out during their sequestration and after they returned to the war-torn world.

The Subcommittee has already noted the conditions that will confront survivors who have found shelter. Without adequate food, water, or electricity, shelter occupants will succumb to malnutrition, sickness and, depending on the time of year, the extremes of intense heat or cold. Further, for those who are able to survive the hardships of shelter life, the atmospheric uncertainties previously described will make the outside world anything but an inviting place in which to start the process of reconstruction. Accordingly, the Subcommittee seriously questions the use of shelters as a significant means of mitigating the post-attack health and ecological consequences of nuclear war.

The third approach is to evacuate target areas so as to mimimize casualties. However, here, too, the Subcommittee believes that such plans are so fraught with uncertainty and danger as to render them useless. By most accounts including estimates of the Federal Energy Management Administration, between 3 and 8 days would be required to move people out of the Nation's major cities.[92] However, even assuming that more warning time is available than the 30 or so minutes required for an ICBM to traverse the Northern Hemisphere, the relocated populace would be an open target for retargeting should that be the wish of a foe. Further, once away from whatever protection and shelter are afforded by urban structures, the relocated population would be exposed to radiation from an attack on the abandoned cities. Finally, given that the degree and direction of destruction from a nuclear attack will be function of a number of unpredictable variables,[93] there seems to be no way of planning in advance a plausible evacuation scenario.

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[90] Since the hearing, the Subcommittee has become aware of a new book that is pertinent to this issue and to later-discussed related matters. See "With Enough Shovels," by Robert Scheer.

[91] Statement of Dr. Sidney Drell (p. 6) at Nuclear Aftermath hearing.

[92] Response of H. Jack Geiger to Supplemental Question 1 posited by the Subcommittee following the nuclear aftermath hearing.

[93] Statement of Dr. Sidney Drell (p. 6) at note 40 *supra*. Among the uncertainties are: (i) At what time of year will the attack take place? Since different wind patterns accompany different seasons, the direction of lethality will vary from month to month. (ii) Will cities actually be targeted, or will many cities be at the periphery of military targets? If the latter, for many individuals, it may be better to remain home where there is at least some shelter against fallout. (iii) Will the bombs be air burst or ground burst? If air burst, than the distance one must travel to escape the heat and blast effects is greater than if ground burst. If ground burst, then protection from radiation becomes more important than in the case of an air burst.

With all of these imponderables, why is evacuation even considered as a civil defense technique? The answer seems to be grounded in the perception that the Soviets are planning for evacuation and that, accordingly, we should as well. Yet, the fact remains, there has never been a full scale rehearsal of the evacuation of a Soviet City.[94] This is not surprising since the Soviets must know, as we do, that evacuation of any large city—whether as a rehearsal or in earnest—would take days and that the process of evacuation would be greatly alarming to an adversary.

2. Issue.—Is it likely that the damage inflicted on the environment by a large-scale nuclear war will render moot the question of who won or lost the war?

Findings.—Yes. Aside from the death toll, areas made uninhabitable by radiation and destruction of military, petrochemical, and industrial targets, large-scale nuclear war could wreak havoc with mankind's environment. Accordingly whether or not a combatting nation can claim military victory, the cost of such "victory" may well be the loss of a sustainable environment.

As previously noted, since the September 15, 1982 hearing, the Subcommittee has become aware of Robert Scheer's book, entitled, "With Enough Shovels." In his book, Scheer quotes from a Foreign Policy article written by Colin Gray, a nuclear war expert and arms control advisor to the Reagan Administration. Scheer characterizes the excerpt as "the nuclear war-fighter's alternative vision:" [95]

> The United States should plan to defeat the Soviet Union and to do so at a cost that would not prohibit U.S. recovery. Washington should identify war aims that in the last resort would contemplate the destruction of Soviet political authority and the emergence of a post war order compatible with western values.

What the Subcommittee discovered from the testimony that was given to it on September 15 is that the cost of a nuclear war may not only be prohibitive to Washington (and to Moscow) but, in addition, to all mankind. Short of experiencing a nuclear war, itself, the longer term post-war prospects raised by the witnesses' testimony cannot be irrefutably proven. Nevertheless, what the Subcommittee has concluded, on the basis of such testimony, is that nuclear war will leave little room for the emergence of a post-war recovery that in any way resembles the values or life style that now characterizes Western civilization. To the contrary, for Westerner and Eastern alike, we may now be discovering that, because of the global environmental effects that could be unleashed, nuclear war may threaten not only our civilization but our very survival as well.

3. Issue.—Has there been an orderly, well-coordinated examination of the post-war health and ecological risks of nuclear war?

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[94] *Id.* in response to supplemental questions posited by the subcommittee.

[95] "With Enough Shovels," at page 12. See also Colin S. Gray and Keith Payne, "Victory is Possible," Foreign Policy, Summer 1980 at 14-27.

Findings.—No. Much of what is known today is the product of isolated discoveries of interested scientists coupled with the recording of chance happenings.

At the Subcommittee's hearing, one of the witnesses suggested that the sun screening theory raised by Dr. Birks and Crutzen evoked thoughts of a popular theory which holds that the death of the dinosaurs some 65 million years ago was due to darkening caused by dust from the collision of a large extraterrestial body with the Earth.[96] That these scientists, as well as others from whom the Subcommittee's staff has sought advice, would draw this connection is extraordinarily sobering. Obviously as sobering was the testimony of one witness who declined to rule out the possibility that the impact of nuclear war on the Earth's biosphere could be so drastic as to ultimately lead to the extinction of the human species.[97] Though not all of the witnesses drew this conclusion with some raising questions as to the possible survivability of the Southern Hemisphere,[98] each foresaw destruction that went far beyond the blast, radiation and thermal heat wave that, almost instantaneously, would take the lives of tens to hundreds of million of people in the event of a nuclear war.

Of further importance, while each witness offered his own assessment of the horror that would be occassioned by a nuclear conflict, none thought it preposterous to raise the question of whether this nation or any other could survive a nuclear attack. Indeed, one witness even quoted the Deputy Director of the Soviet Ministry of Health and former personal physician to Chairman Breshnev as having said that, in the event of a nuclear war, the Soviet Union would be destroyed for generations.[99]

Yet, while information regarding the effects of nuclear war continues to cumulate, the Subcommittee could not help but be struck at how random and uncoordinated the amassing of such knowledge has been. For example, how would we know about the potential for sun screening had not the Swedish Academy of Sciences had the foresight to commission a study of the atmospheric effects of nuclear war and had not Dr. Birks and Dr. Crutzen the prescience to consider the consequences of massive forest fires? Theirs was at least the product of a scholarly effort aimed specifically at learning more about the effects of nuclear war. By contrast, aside from isolated studies such as the 1975 NAS studies and the work now being done by Drs. Chang and Tsipis much of what we have learned about the atmospheric and ecological effects of nuclear war has been the result of trying to assimilate the isolated work products of interested scientists coupled with the occurrence of chance happenings.

Had it not been for the fact that the infelicitously named Luck Dragon Japanese fishing vessel was caught in the fallout from a test blast in Binkini Island better than one hundred miles away, we would not know about the effects on humans of radiation fallout. Nor, would we know about the extensive reach of fallout patterns were it not for the investigations following Secretary Schlesinger's 1974 statement that only 15,000 to 25,000 persons would perish in a nuclear war. Nor would we know about the effects of nuclear blasts on the ozone layer were it not for the environmental controversy that surrounded the early development of supersonic transport. Though the Subcommittee acknowledges that not all such effects could have been anticipated through laboratory research, it, nevertheless, believes that the matter is so far too important to merely rely on chance.

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[96] Testimony of Dr. Sidney Drell at Nuclear Aftermath hearing at transcript 829. The same sentiment was expressed by Drs. Birks and Crutzen at page 6 of their statement.

[97] Testimony of Dr. Arthur Westing note 86 *supra* at transcript 2870.

[98] Testimony of Dr. Sidney Drell note 90 *supra* at transcript 820–32.

[99] Testimony of Dr. Herbert Abrams note 19 *supra* at transcript 2076.

4. Issue.—Are there scientific uncertainties that still remain?

Findings.—Many questions remain to be answered, in particular, questions involving the relationship between nuclear explosions and atmospheric chemistry, the potential for climate alteration and the relationship between ozone depletion and blindness.

Though the Subcommittee recognizes that each scientific team will choose its own area of inquiry, the following lines of research were suggested by the Subcommittee's hearings:

(1) What climatic effects may be induced by nuclear war?

(2) In addition to the risk of eye damage, what other harmful affects are associated with enhanced levels of ultra violet radiation?

(3) To what degree is eye damage from ultra violet radiation a significant risk at ozone depletion levels of less than 50%.

(4) To what degree will the Southern Hemisphere be spared the ecological and atomospheric effects of a war fought primarily in the Northern Hemisphere?

(5) Is it likely that atmospheric chemical effects will neutralize or offset the otherwise harmful effects of sun screening or ozone depletion?

(6) Will ionizing radiation contaminate ground water sources and what might be the extent of such contamination?

(7) What is the effect of multiple targeting of weapons, i.e., tunneling, on depletion of the ozone layer?

(8) What will be the effect on plankton, and therefore, the marine food chain, of high levels of ionizing and/or ultra violet radiation?

V. CONCLUSION

Whatever the nature of a nuclear attack, it is fair to assume that scores of millions of persons in the Northern Hemisphere will survive the immediate heat and blast effect of a large-scale nuclear war as well as the residual radiation. The serious question raised by the Subcommittee at the September 15 hearings was what kind of world would await these survivors as they emerged from their places of refuge in search of food.

Much new and sobering information on the nuclear aftermath issue was brought to light as a result of the Subcommittee's hearing. However, there is much more information that must be amassed. Further, the importance of the subject matter and the direction that it might give to leaders both here and abroad warrants that the greatest effort be made in resolving those aspects of the problem that lend themselves to solution.

In the last section of its report, the Subcommittee has suggested some areas of further research that have the potential for resolving some of the unanswered questions that still remain. What the Subcommittee seeks to promote by suggesting these avenues of inquiry is an earnest effort by the international scientific community, perhaps, akin to the 1957 International Geophysical Year.

VI. APPENDICES

1. Nuclear force posture used in 1979 OTA Study, "The Effects of Nuclear War."
2. Warheads, megatonnage and targeting pattern for Ambio reference scenario.
3. ACDA map of area subjected to 1000 rems in the event of a full scale nuclear attack (from the "Effects of Nuclear War," ACDA 1979 at p. 21).
4. Population Density of the Two Germanies and Fallout Pattern from Limited Nuclear War Using Theoretical 200 Kiloton Nuclear Weapons.
5. 100 rad worldwide fallout pattern from targeting of nuclear powerplants (from Ambio, note 7 *supra* at pp. 98–99).
6. CRS Estimated 1983 inventory of deployed U.S. and U.S.S.R. Strategic Offensive Weapons, assuming current Salt II Guidelines.
7. Dangerous Myths about Nuclear War, Edward Teller.
8. Witness List.

Appendix 1

Estimated U.S. Strategic Nuclear Forces, 1985

Launcher	Number	Warheads per launcher	(Mid-1980's force)			Equivalent megatons
			Total warheads	Yield in megatons	Total megatons	
Minuteman II	450	1	450	1.0	450.0	450
Minuteman III	550	3	1,650	0.17	280.5	512
(with MK-12A)	(550)	(3)	(1,650)	(0.35)	(572.5)	(825)
Titan II	54	1	54	9.0	486.0	232
Total ICBMs......	1,054		2,154		1,216.5 (1,508.5)	1,194 (1,507)
Poseidon	336	10	3,360	0.04	134	403
Poseidon C-4.......	160	8	1,280	0.10	128	282
Trident I	240	8	1,920	0.10	192	422
Total SLBMs	736		6,560		454	1,107
B-52 G/H	165	6 SRAM	990	0.2	198	337
		4 bombs	660	1.0	660	660
B-52CM	165	20 ALCM	3,300	0.2	660	1,122
FB-111...........	60	2 SRAM	120	0.2	24	41
		2 bombs	120	1.0	120	120
Total bombers	390		5,190		1,662	2,280
Grand total.......	2,180		13,904		3,332.5 (3,629.5)	4,581 (4,894)

SOURCE: *Counterforce Issues for the U.S. Strategic Nuclear Forces*, Congressional Budget Office, January 1978.

Estimated Soviet Strategic Nuclear Forces, 1985

Launcher	Number[a]	Warheads per launcher[b]	Total warheads	Yield in megatons[c]	Total megatons	Equivalent megatons
SS-11	330	1	330	1.5	495	432
SS-17	200	4	800	0.6	480	560
SS-18	308	8	2,464	1.5	3,696	3,228
SS-19	500	6	3,000	0.8	2,400	2,580
SS-16	60	1	60	1.0	60	60
Total ICBMs......	1,398		6,654		7,131	6,860
SS-N-6........... SS-N-8...........	600	1	600	1.0	600	600
SS-N-17.......... SS-N-18..........	300	3	900	0.2	180	306
Total SLBMs	900		1,500		780	906
Bear.............	100	1	100	20	2,000	740
Bison	40	1	40	5	200	116
(Backfire)	(250)	(2)	(500)	(0.2)	(100)	(170)
Total bombers	140 (390)		140 (640)		2,200 (2,300)	856 (1,026)
Grand total.......	2,438 (2,688)		8,294 (8,794)		10,111 (10,211)	8,622 (8,792)

SOURCE: *Counterforce Issues for the U.S. Strategic Nuclear Forces*, Congressional Budget Office, January 1978.

Appendix 2

Ambio

Warheads and megatonnage, Reference Scenario.

A. Total number of warheads used: 14 747
Total megatonnage used: 5742 Mt

Megatonnage used in Northern Hemisphere: 5569 Mt
Megatonnage used in Southern Hemisphere: 173 Mt

B.

Size of warheads	**Number used**
100 kt	939
200 kt	2930
300 kt	4410
500 kt	5692
1 Mt	769
10 Mt	7

C. **Numbers of warheads used for different target categories,**
Megatons used for different target categories:

Military targets:	6620 warheads	2960 Mt
Population (1124 cities:)	4970 warheads	1941 Mt
Industry/Energy	3136 warheads	701 Mt
Closing of straits (14 straits)	21 warheads	140 Mt

D. **Warheads used for different target categories:**

Military	300 kt	(one 300-kt warhead per target)
	100 kt	(one 100-kt warhead per target)
	200 kt	(one 200-kt warhead per target)
ICBM		(two 500-kt warheads per silo)
Submarine Bases		(one 1-Mt warhead per base)
Population	1 Mt	(three 300-kt + one 100-kt per city)
	3 Mt	(three 1-Mt warheads per city)
	10 Mt	(ten 500-kt – five 1-Mt warheads per city)
Industry	1 Mt	(five 200-kt warheads per site)
Oil fields	1 Mt	(two 500-kt warheads per site)
Closing of straits	10 Mt	(seven 10-Mt + fourteen 500-kt warheads) (this is total for the 14 straits)

E.

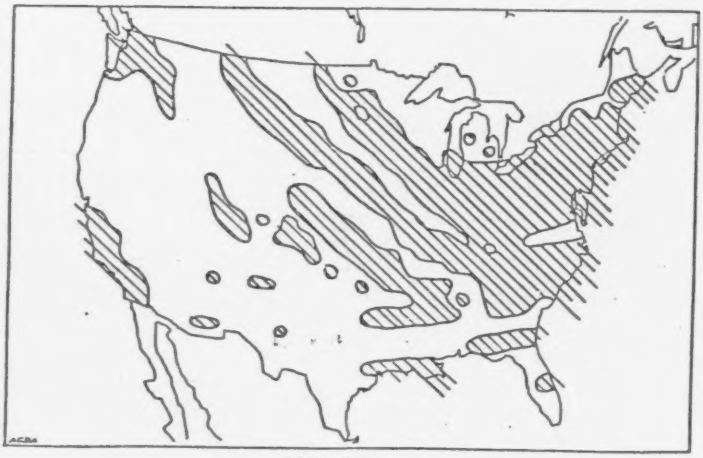
Military targets.	**Megatonnage per target (average)**	
Air bases	300 kt	ground burst
Naval ports	300 kt	ground burst
Army bases	300 kt	ground burst
Command/control/radar	300 kt	ground burst
Early warning systems	100 kt	ground burst
SOSSUS	300 kt	water burst
ICBM	Two 500 kt warheads per silo	ground burst
Energy Resources targets:		
Hydro electric stations	10 kt	airburst
Other energy resources	10 kt	airburst
Oilfields	1 Mt	airburst
Industrial targets:		
(only large industrial complexes)		
Oil refineries	1 Mt	airburst
Chemical plants (heavy organics, urea/nitric acid, sulfuric acid, ammonia)	1 Mt	airburst
Cement	1 Mt	airburst
Iron ore/steel	1 Mt	airburst

Appendix 3

UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY

THE EFFECTS OF NUCLEAR WAR

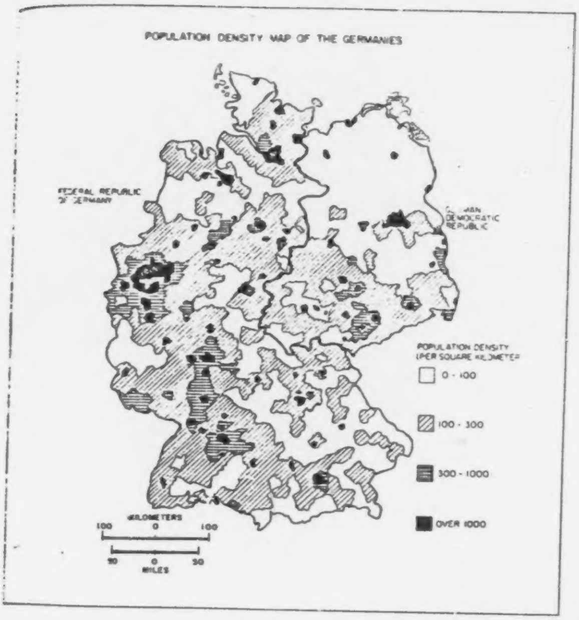
AREAS COVERED BY 1000 REMS OR MORE

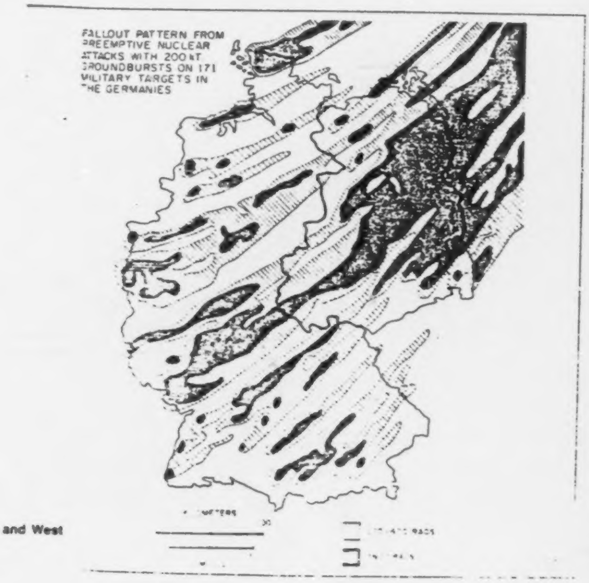


1000 REM

April 12, 1979

Appendix 4


POPULATION DENSITY MAP OF THE GERMANIES
FEDERAL REPUBLIC OF GERMANY
GERMAN DEMOCRATIC REPUBLIC
POPULATION DENSITY (PER SQUARE KILOMETER)
☐ 0 - 100
▨ 100 - 300
▤ 300 - 1000
■ OVER 1000
KILOMETERS
100 0 100
50 0 50
MILES

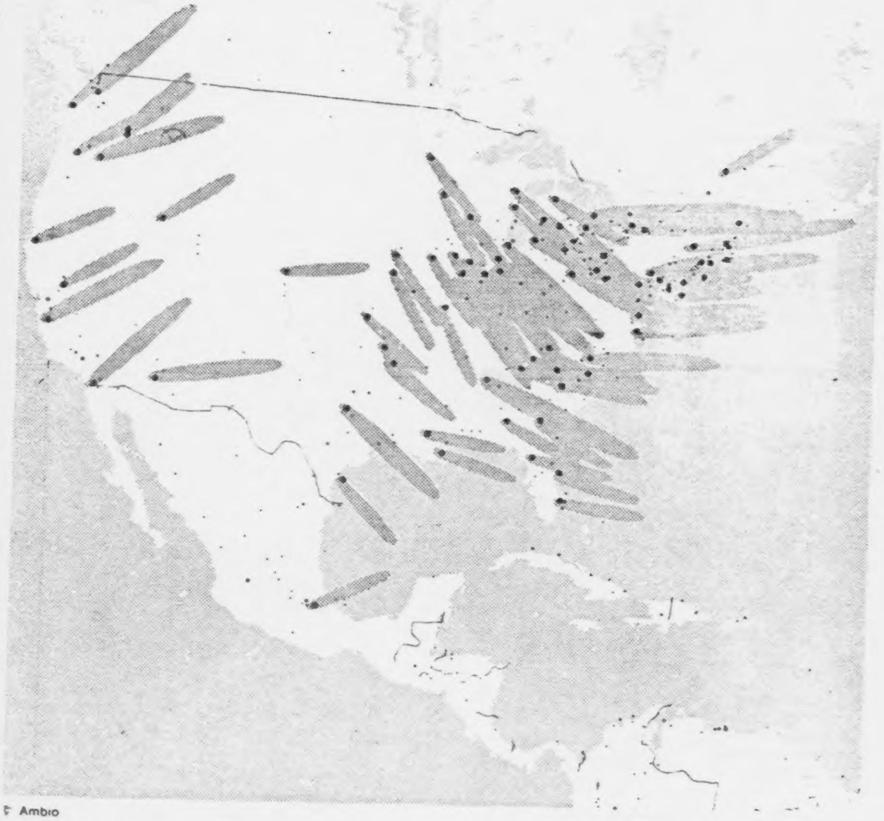

FALLOUT PATTERN FROM PREEMPTIVE NUCLEAR ATTACKS WITH 200 kT GROUNDBURSTS ON 171 MILITARY TARGETS IN THE GERMANIES

Ambio Vol 11, No. 2-3, pp 143-148, 1982

The Consequences of a "Limited" Nuclear War in East and West Germany
W Arkin, F von Hippel, B G Levi

Appendix 5(a)

shaded areas correspond to a dose of 100 rad
at 1 year starting one month after the detonation.



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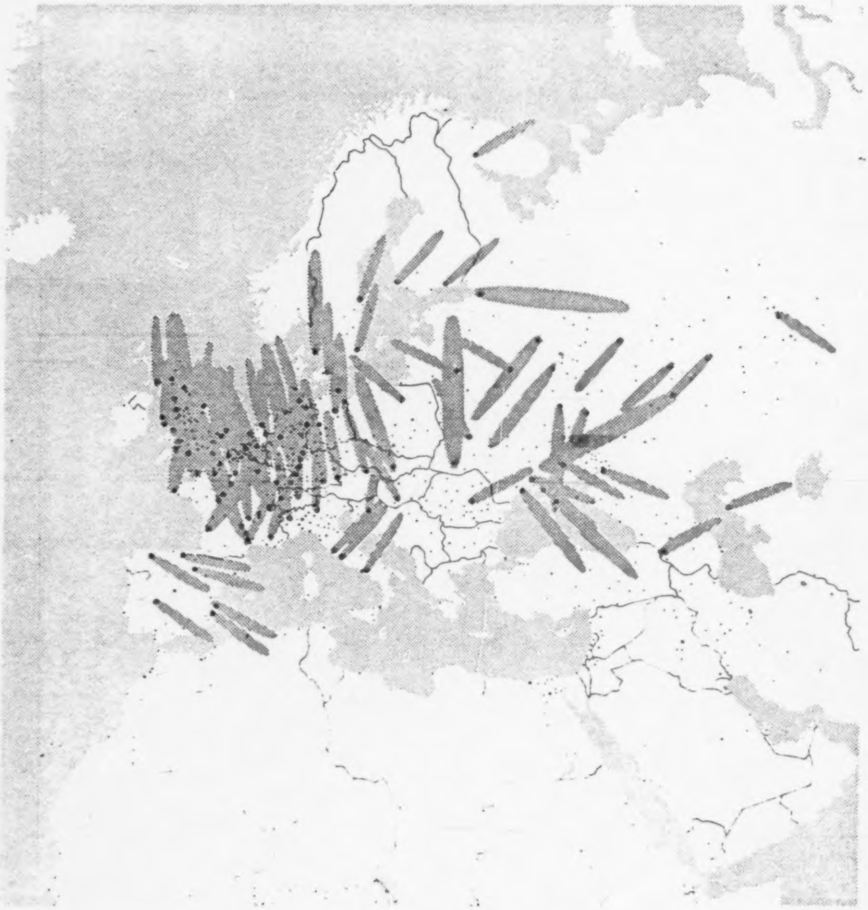
Ambio Vol 11, No. 2-3, pp 100-105, 1982

Appendix 5(b)

shaded areas correspond to a dose of 100 rad
at 1 year starting one month after the detonation



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Ambio Vol 11, No. 2-3, pp 100-105, 1982

Appendix 6(a)

ESTIMATED 1983 INVENTORY OF DEPLOYED U.S. STRATEGIC OFFENSIVE WEAPONS UNDER CURRENT SALT II GUIDELINES

Delivery Vehicle (DV)	Number of DVs	Warheads Per DV	Sub-Total Warheads	Yield Per Warhead (MTs)	Sub-Total Yield (MTs)
ICBMs: 1/					
Minuteman III (MK-12A)	300	3	900	0.335	301.5
Minuteman II (MK-12)	300 2/	3	900	0.17	153
Minuteman II	400 2/	1	400	1.2	480
Sub-Totals	1000		2200		934.5
SLBMs:					
Poseidon (19 Lafayette)	304	9 ave.	2736	.04	109.4
Trident I	264	8	2112	0.100	211.2
(12 Lafayette)	(192)				
(3 Ohio)	(72)				
Sub-Totals	568		4848		320.6
Heavy Bombers:					
B-52D	40 3/	2 SRAMs +	80	0.17	13.6
		4 bombs	160	1.2 ave.	192
B-52G	100	4 SRAMs +	400	0.17	68
		4 bombs	400	1.2 ave.	480
B-52G CMC	51	12 ALCMs +	612	0.2	122.4
		4 SRAMs +	204	0.17	34.7
		4 bombs	204	1.2 ave.	244.8
B-52H	90	4 SRAMs +	360	0.17	61.2
		4 bombs	360	1.2 ave.	432
Sub-Totals	281		2780		1648.7
TOTALS	1849		9828		2903.1

1/ Titan II ICBMs are scheduled to be retired in 1982 and 1983.

2/ 50 of the 450 Minuteman II launchers have been authorized to be converted to launchers for Minuteman III. Consequently, the total number of Minuteman IIIs deployed will be 600 and the number of Minuteman IIs will drop to 400.

3/ B-52D bombers are scheduled to be retired starting in 1983. Currently, 75 B-52Ds are deployed.

Appendix 6(b)

ESTIMATED 1983 INVENTORY OF DEPLOYED SOVIET STRATEGIC OFFENSIVE WEAPONS

UNDER CURRENT SALT II GUIDELINES

Delivery Vehicle (DV)	Number of DVs	Warheads Per DV	Sub-Total Warheads	Yield Per Warhead (MTs)	Sub-Total Yield (MTs)
ICBMs:					
SS-18 (1 RV)	58	1	58	20	1160
SS-18 (8 RVs)	150	8	1200	0.9	1080
SS-18 (10 RVs)	100	10	1000	0.55	550
SS-19 (1 RV)	60	1	60	10	600
SS-19 (6 RVs)	300	6	1800	0.55	990
SS-17 (1 RV)	32	1	32	6	192
SS-17 (4 RVs)	120	4	482	0.75	361.5
SS-11 (1 RV)	518	1	518	0.95	492.1
SS-13 (1 RV)	60	1	60	0.6	36
Sub-Totals	1398		5210		5461.6
SLBMs:					
SS-N-20 (3 Typhoons)	60	10	600	0.2	120
SS-N-18 (15 Delta III)	240	7	1680	0.200	336
SS-N-17	60	1	60	0.75	45
(1 Yankee II)	(12)				
(3 SSBN-X)	(48)				
SS-N-8	286	1	286	0.8	228.8
(4 Delta II)	(64)				
(18 Delta I)	(216)				
(1 Hotel III)	(6)				
SS-N-6 (19 Yankee I)	304	1	304	0.7	212.8
Sub-Totals	950		2930		942.6
Heavy Bombers:					
TU-95 Bear	113		227		227
(Kanmgaroo)	(75)	1	(75)	1.0	(75)
(Bombs)	(38)	4	(152)	1.0	(152)
Mya-4 Bison (Bombs)	43	2	86	1.0	86
Sub-Totals	156		313		313
TOTALS	2504		8453		6717.2

Witness List

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Appendix 7

Dangerous Myths About Nuclear Arms

By Edward Teller

Educating people about the nature and actual perils of nuclear weapons would not be easy under any circumstances. It is almost impossible when elementary facts are guarded by strict regulations of secrecy. Given such conditions, dangerous myths develop and proliferate.

The reality of nuclear weapons is grim enough. Exaggerations about them are apt only to paralyze us. Some of the current myths have grown from misinterpreted scientific studies; others seem to be based on simple wishful thinking. They all have one common characteristic: so long as they are believed, they obstruct an accurate assessment of our problems and will prevent the development of workable plans to preserve peace.

Myth 1: The Soviet and American nuclear stockpiles are close to identical. A nuclear freeze would stop the arms race and offer improved mutual protection.

Neither the United States nor the Soviet Union publishes information on its current arsenals, and secrecy laws prevent me from discussing even the available estimates. There is, however, an officially released fact: between 1966 and 1981 the total megatonnage of the American nuclear arsenal was *reduced* to less than one-half its former size. The Soviet arsenal has rapidly increased in yield, accuracy and diversity during the same period and currently includes a total nuclear explosive power in excess of what the United States *ever* had.

The Soviets have built the most powerful single weapons ever constructed. Militarily such weapons have very limited value, but as a blackmail threat against free-world cities, they seem to be quite effective. Weapons of such immense size are the most likely to cause damage to the earth's ozone layer (which acts as a shield against lethal amounts of ultraviolet radiation)

Dr. Edward Teller, physicist, was instrumental in the development of the H-bomb, and is currently a Senior Research Fellow at the Hoover Institution at Stanford University.

and lower the global temperature. A movement that says "freeze the current arsenals as they are" grants acceptability to these extraordinarily destructive Soviet weapons when they should be vigorously opposed.

By comparison with the Soviet Union, we have but a small fraction of the world's existing nuclear megatonnage. We do have sufficient power to create great damage, particularly to the Soviet industrial plant, *if* our retaliatory forces are safe from a first strike. They are not safe, however, and their deterrent effect has become doubtful.

***Myth 2:** Each nation has the power to destroy the other totally. Mutual destruction can most surely be avoided by disarming.*

Our nuclear defense strategy, Mutually Assured Destruction, has the most appropriate acronym of MAD. The theory: if the Soviet Union and the United States have their urban populations at risk, then neither will attempt a first strike.

The Soviets have never agreed to the ideas on which MAD is based. The landmass of the U.S.S.R. is more than twice that of the United States; its urban concentration proportionately much lower. The Soviets' civil-defense planning may well enable them to lose fewer people in a nuclear conflict than the 20 million or more casualties they suffered in World War II.

Disarmament (as opposed to simple surrender) must be based on openness or trust. The extreme reticence of the Soviets to allow on-site inspections has been a continuing problem since 1958. Our basis for trust has not grown since. Recently declassified information offers an example of our problems. Since silos but not missiles can be counted by aerial surveillance, the SALT treaty limited silos. The obvious objective was to limit the number of deliverable missiles. The American silos are not reloadable. The Soviet silos are. This is not a breach of the treaty. American negotiators, neglecting the possibility that the Soviets might not have an equal urge to disarm, failed to insert an essential clause.

We have negotiated for 25 years, and the results are readily visible. Why would a totalitarian empire that depends on military force to maintain its power voluntarily disarm itself?

***Myth 3:** Stopping U.S. weapons research and development will help make the world safer from the destructive effects of nuclear weapons.*

For more than 25 years the primary purpose of U.S. weapons laboratories has been to make nuclear weapons *less* indiscriminately destructive. Cleaner bombs (with less fallout), smaller, more militarily effective weapons, and neutron bombs useful for battlefield defense (with less civilian damage than that created by a conventional artillery barrage) are among the results.

Furthermore, extremely important research is being conducted on systems to defend against incoming nuclear missiles. For example, exploding a very small nuclear bomb near an attack missile as it enters the upper-to-middle atmosphere over our nation would have no effects on the ground and negligible effects on the atmosphere, but could totally *disarm* the incoming missile without *detonating* it. Such a system, used to protect our vulnerable missile silos, could be an important first step in improving both our current retaliatory position and directing our policy toward defense. The nuclear-freeze movement would end further work on what could be the best defense systems.

The Soviets have already deployed an antiballistic-missile system around Moscow. We have the right to deploy a similar system but have not done so. The Soviet-American antiballistic-missile treaty is now being reviewed. We should change our policy and emphasize defense rather than retaliation.

***Myth 4:** If a large number of nuclear weapons were exploded, fallout would pollute food and water supplies, making combatant countries uninhabitable. The spread of radioactive fallout throughout the world would end life on earth.*

Fallout is part of many myths, and one of the common misunderstandings has to do with the durability and extent of its effects.

The radioactivity of fallout declines rapidly. For example, if 1000 rems per hour (a lethal dose) were released by a bomb, seven hours later the dose would be 100 rems per hour (far below lethal). In 49 hours radiation from this fallout would be reduced to 10 rems per hour. In 100 days the radiation would be 0.1 rems, comparable to the amount received from a chest X ray.

The amount of radioactivity produced by a bomb, contrary to myth, is finite. Radiation from fallout of the intensity described would be limited to the immediate vicinity of the explosion and the adjacent areas downwind. People in these areas could move to uncontaminated regions. (Decontamination is feasible if we prepare for it.)

Fallout in the vicinity of a nuclear explosion is a visible material, an ash. It can be wiped or washed off cans, wrappers, skin or any other surface. It can be easily filtered out of water. Food exposed to fallout is not harmed by the radiation. In fact, radiation is used commercially for food preservation. The only risk connected with food is if the fallout itself is eaten in the food or through some part of the food chain.

Skin contact with fallout is not necessarily fatal—depending on the intensity of the radiation and the precautions taken. Injuries can be reduced simply by washing off the ash. Through tragic miscalculation, 23 Japanese fishermen were covered with fallout from the multi-megaton test at Bikini Atoll in 1954. The fallout reached their boat three hours after the explosion and continued for an additional 4½ hours. They made no effort to brush or wash off the ash. All suffered skin lesions, most had appetite loss, some experienced nausea and vomiting. One died shortly afterward, and two others died 20 years later of liver disorders that may have been associated with the fallout. The rest have survived. Simple knowledge on how to deal with fallout would practically have eliminated the effects.

There would be numerous dreadful real consequences if a nuclear exchange occurred. Preventing war—in particular, nuclear war—is our single most important task. Should nuclear war occur in spite of every good effort, the number of people killed would be truly terrifying, but many more would survive. Perhaps this is the most frightening thing about our current myths: the misconceptions that exist currently would intensify the fear and suffering of survivors needlessly.

Myth 5: *The explosion of nuclear weapons in the atmosphere will bring an end to life on this planet by damaging the ozone layer.*

This new doomsday myth is gaining popularity. What we know today about the ozone layer suggests that if weapons larger than half-megaton bombs—such as only the Soviets possess—were exploded in the atmosphere, they would generate considerable amounts of nitrogen oxides at high altitudes. These oxides continue to destroy ozone over a protracted period. If the ozone were depleted, more ultraviolet radiation would reach the earth.

Assuming a worst-case scenario—a nuclear attack in which 5000 weapons, all of 1-to-20-megaton size, were exploded in the atmosphere—there would probably be a 50-percent decrease in the ozone layer over the Northern Hemisphere during the following year. (In the next few years, the ozone layer would return to about 80 percent of normal.) If this occurred, people would suffer rapid sunburn and a significant increase in skin cancer. Some ultraviolet-sensitive species could be extinguished, and some serious ecological changes might follow. However, our survival can be considered certain.

More detailed scientific information about the ozone layer is needed and should be gathered on an international basis. In the meantime, limiting the explosive power of all individual nuclear weapons to 400 kilotons would effectively eliminate the possibility of any significant damage to the ozone layer. Such a limitation should become an important part of disarmament talks.

Myth 6: *Civil defense is without value in saving lives and may actually increase the risk of war.*

This is perhaps the most dangerous myth of all.

Today some Soviet nuclear missiles may carry an explosive force a thousand times greater than the 15-kiloton Hiroshima bomb. However, while the vertical force of the explosion increases a thousand times, the horizontal distance over which such bombs produce equal damage increases much more slowly. For example, a one-megaton bomb, while almost 70 times more powerful than the Hiroshima bomb, produces equal damage over only about four times the distance.

Few people realize the following facts about the effects of the Hiroshima and Nagasaki bombings. Earth-covered conventional bomb shelters practically under the airburst atomic bombs were essentially undamaged even though blast and fire destroyed all other buildings in the area. In Nagasaki, people in caves survived one-third of a mile from ground zero. In Hiroshima, a well-built wood-frame house one mile away from ground zero was badly damaged but stood. The day after the blast, bridges were open to traffic; the second day, trains ran; the third day, streetcars were operating. The people of these cities were without any knowledge of how to protect themselves. Yet 1.6 to 3.1 miles from ground zero, 98 percent of the inhabitants—283,000 people—survived. Among this group in the past 33 years, about 500 more deaths from cancer have occurred than would be predicted in an unexposed similar group of people.

What about predictions of genetic damage? Detailed analyses have been made of about 35,000 children born to atomic-bomb survivors. So far no evidence of genetic damage has been found. This does not mean that none exists. However, genetic damage compared with the other horrors of nuclear war is practically negligible. Radiation during pregnancy—especially in the early stages—is very harmful to the fetus. More than one quarter of the infants born five to nine months after the bombing suffered from retarded growth, including mental retardation. About seven percent of those born in the four months following the bombing also suffered these defects. Yet the myth suggests that all fetuses tragically exposed by nuclear war will suffer developmental malformation. The actual effects of atomic weapons are ghastly enough. Exaggeration discourages reasonable measures to protect those most vulnerable.

Under Soviet civil-defense plans, nonessential city workers would be evacuated if the immediate danger of war (or intent for a Soviet first strike) arose. The evacuees would build crude but effective shelters in the countryside according to well-prepared instructions. (Tests of the Soviet shelter plans at Oak Ridge National Laboratory show them to be excellent.) With optimum conditions, these plans would allow the Soviet Union to protect all but about 5 to 10 percent of its people from a full retaliatory strike. Well over 50 percent of the unprepared U.S. population would die in a nuclear attack. This need not be so. Comparable civil-defense planning in the United States could save 100 million more lives.

War has always been more terrible than words can describe. Nuclear war would create immense suffering. Surely taking out some insurance against increased suffering is neither wasteful nor inhumane. We could accomplish so much for so little were we to spend only one percent of our defense budget on civil defense.

Planning the evacuation of urban residents and stockpiling food already owned by the government in the corresponding evacuation areas is a most important cheap insurance policy. Were the Soviets aware that the American people are able to survive an attack, they would be much less likely to take the risk of initiating a conflict. And can you really believe that civil defense will make the American people or our government more likely to risk nuclear war?

OUR FIRST STEP toward stability, toward improving the prospects for peace and for the security of all people, must be the replacement of myths with knowledge. Only then can we approach the best possible solutions. They will not be perfect. But they will offer the chance for improvement—of changing mutually assured destruction into a decent chance of survival, of maintaining sufficient military strength to coax Soviet leaders toward real détente. If our salvation is to be real, it must be based on fact, not fantasy.

For information on reprints of this article, see page 297

VII. MINORITY VIEWS

REVIEW OF THE CONSEQUENCES OF NUCLEAR WAR ON THE GLOBAL ENVIRONMENT

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

The Minority concur that the effects of a nuclear war would be truly devastating and that a review of what some scientists believe to be the environmental consequences of such an event is appropriate.

We take issue, however, with the timing of the report's release. The hearing upon which the report is based was held on September 15, 1982, during the 97th Congress. Traditionally, and we think for good reasons, subcommittee reports are issued in the same Congress in which the original hearing was held. This policy is a wise one, and is especially important in protecting the rights of the Minority. To illustrate the problem, we would like to review our current situation on this report. First, none of the minority members who served on the subcommittee in the 97th Congress still serve on the subcommittee in the current Congress. In addition, the minority counsel serving the minority members in the 97th Congress is no longer with the subcommittee. The result places the minority members currently on the subcommittee in the untenable position of approving a controversial report without having the benefit of participating in the hearing or from the advice of the minority staff serving the subcommittee at that time.

We are being asked, subsequently, to support the issuance of a report in an informational and policy vacuum. We therefore have no basis upon which to judge the merits of the report's recommendations. We strongly disagree with this process, and feel it is indecorous for this subcommittee.

We support the committee's oversight activities in this area nevertheless, and look forward to the ongoing discussion of the issue.

JOE SKEEN.
CLAUDINE SCHNEIDER.
AL MCCANDLESS.

VIII. DISSENTING VIEWS

We are all deeply concerned about the consequences of *any* use of nuclear weapons because we realize that *any* nuclear war, regardless of the scope of the nuclear force utilized, would be a catastrophe for all mankind. We agree that the potential consequences should be examined and discussed, and we feel strongly that any such discussion should be based on valid and well documented scientific data, and not on polemics arising from opinion and preconceptions.

To quote the excellent OTA study "The Effects of Nuclear War" (Library of Congress Catalog Card Number 79-600080), which was published in 1979:

> Nuclear war is not a comfortable subject. Throughout all the variations, possibilities, and uncertainties that this study describes, one theme is constant—a nuclear war would be a catastrophe. A militarily plausible nuclear attack, even "limited," could be expected to kill people and to inflict economic damages on a scale unprecedented in American experience; a large-scale nuclear exchange would be a calamity unprecedented in human history. The mind recoils from the effort to foresee the details of such a calamity, and from the careful explanation of the unavoidable uncertainties as to whether people would die from blast damage, from fallout radiation, or from starvation during the following winter. But the fact remains that nuclear war is possible, and the possiblity of nuclear war has formed part of the foundation of international politics, and of U.S. policy, ever since nuclear weapons were used in 1945.[1]

Our first major concern regarding this report from the Committee on Science and Technology is that while it appears to be a serious scientific study of the possible environmental consequences of a nuclear war, in fact, it is based on an extraordinarily limited examination of the available data. It ignores a tremendous amount of excellent, and fully documented and peer reviewed data which were already available in well recognized American scientific literature. It relies almost totally on materials published in a single study in Ambio, the journal of the Swedish Academy of Sciences. While we do not denegrate Ambio, we cannot understand why the wealth of well recognized data available in the materials we have listed as an appendix to our views were not utilized in any consideration of this important topic.

It would seem to us that the Committee on Science and Technology has an affirmative duty to ourselves, to the House, and to the

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[1] "The Effects of Nuclear War," OTA, U.S. Congress, 1979, p. 3.

American people to be careful to present issues based on a broad range of scientific data and in a way that does not present a slanted or incomplete view. There are those who still instinctively fear the power of the atom, and a slanted report could easily manipulate that instinctive fear. To quote the World Health Organization Technical Report, "Mental Health Aspects of the Peaceful Uses of Atomic Energy":

> There is, however, reason to believe that certain emotional responses are provoked by the advent of atomic energy also in a more direct manner and must in many instances, be considered as pathological. These responses, which seem to be due partly to the circumstances in which atomic power has been introduced and partly to its very nature, constitute perhaps the most important mental health aspect of the peaceful uses of atomic energy.
>
> These unhealthy reactions appear to stem from anxiety, and from attempts which human beings make to deal with anxiety. Thus they may be manifested in the form of irrational fears, irrational hopes, or irrational power. Among these reactions, the most frequent is undoubtedly irrational fear, and this fact is certainly of the greatest importance for any analysis in this field.[2]

While the above cited WHO report was developed on the peaceful uses of atomic power, it is obvious that the same fears can be manipulated on questions concerning military uses of nuclear power. We feel a duty to provide both sufficient information, and differing views, so that the reader will be able to make an informed decision on the issues. Included in the main body of this report as Appendix 7 is an article entitled "Dangerous Myths About Nuclear Arms" by Dr. Edward Teller, one of the most respected physicists in the world, and generally considered to be the father of the hydrogen bomb, which appeared in the November, 1982 issue of The Reader's Digest. The article sparked a debate in The Bulletin of the Atomic Scientists between Frank von Hipple, a senior research physicist at Princeton University, and Dr. Teller. At this point we include these articles, which appeared in the March and April 1983 issues of the Bulletin, and particularly commend the source materials which they have cited. In our survey of these citations, we believed that succinctness required including only a representative portion. It should be noted that these scientific investigations (1) have continued for a number of years, indicating long-term concern and (2) make no particular point, either for or against any issue.

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[2] "WHO technical Report," Series No. 151. Geneva, 1957, p. 12.

Frank von Hippel

The myths of Edward Teller

As both so-called superpowers continue to behave as though there were some meaning to the enormous and increasing arsenals of genocidal nuclear destruction, which are being substituted for arms control arrangements on the grounds that the road to negotiation needs to be paved with the proofs of belligerent intentions, it is essential for concerned and thinking individuals to pause and reconsider the entire basis on which present-day U.S.-Soviet nuclear deterrence is founded. Although the confrontational atmosphere created by the Reagan Administration may not be the most conducive to thoughtful and rational analysis, it does provide for the effective operation of the U.S. democratic system. In particular, the American public needs to decide whether our ideological differences with the Soviets demand a willingness on our part to threaten nuclear war to force them to accept our rules of behavior. If not, we have got to start to explore the alternative approaches to "co-existence."

One of the foremost advocates of the confrontational approach is the distinguished nuclear scientist (popularly though inaccurately known as the "father of the hydrogen bomb") Edward Teller. In a recent article in Reader's Digest, *Teller has attempted to "expose" six myths that are inhibiting the essential U.S. military response to "Soviet aggression." In examining Teller's statement of these "myths," I have been led to the conclusion that he has, despite his intention, concisely succeeded in outlining the major issues that must be faced if we are to avoid a nuclear disaster. Far from being myths, the issues confronted by Teller turn out to be aspects of a new examination of U.S. policies in the age of nuclear parity.*

When it comes to mythology concerning nuclear war, it is clear that the American public is well along the route toward demythification. The same cannot be said, I'm afraid, for many of our weaponeers, who still seem to be living in the halcyon (but short-lived) days of the U.S. nuclear monopoly. —*Bernard T. Feld*

In the November 1982 issue of *Reader's Digest*, Edward Teller attacks what he describes as six "dangerous myths about nuclear arms." Teller states in the concluding paragraph of his article that "Our first step toward stability, toward improving the prospects for peace and for the security of all people, must be the replacement of myths with knowledge." Unfortunately, however, the primary focus of Teller's article is not on raising the level of the public debate about the nuclear arms race but on peddling his own myths.

Teller's myths about the nuclear arms race can be roughly summarized as follows:

1. **The Soviets have strategic superiority.**
2. **The U.S. nuclear deterrent has become doubtful.**
3. **The effects of nuclear war could be easily mitigated.**
4. **Soviet civil defense could be highly effective.**
5. **Defensive nuclear weapons could protect us.**
6. **You can't negotiate with the Soviets.**

Since these myths are widely believed within the Reagan Administration and have been popularized by influential groups such as the Committee for the Present Danger as well as by Teller [1], arguments put forward in support of them are well worth examining. For each of Teller's myths, the relevant passages from the *Reader's Digest* article are quoted in italics below and it is then explained why the passages are misleading or false.

1. The Soviets have strategic superiority.

"Between 1966 and 1981 the total megatonnage of the American nuclear arsenal was reduced *to less than one half its former size. The Soviet arsenal has rapidly increased in yield and diversity during the same period and currently includes a total nuclear explosive power in excess of what the United States* ever *had."* (Emphasis in original.)

Because several bombs can accomplish more destruction than a single bomb with the same total yield, total megatonnage is not a very useful measure of the total destructive power of a nuclear arsenal. The ordinary measure of destructiveness against large targets such as cities is "equivalent megatonnage." By this measure, the U.S. arsenal is only about two-thirds as powerful as that of the Soviet Union [2]. The difference is unimportant, however, since both the U.S. and Soviet strategic arsenals are far into the region of "overkill" for such targets. The U.S. arsenal, for example, has today in aggregate about 10 times the destructive power, which would suffice, according to conservative 1968 Department of Defense calculations, to destroy one-third of the Soviet population and three-quarters of its industrial capacity (400 equivalent megatons) [3].

The decline in the megatonnage of the U.S. strategic arsenal between 1966 and 1981 did not occur because of attrition or neglect. It was a by-product of repeated cycles of modernization. Perhaps the most important change has been the replacement of most of the U.S. ballistic missiles which carried a single warhead by missiles with accurate multiple warheads. The effective megatonnage of these missiles has not changed greatly, but the number of military targets they could attack has been increased severalfold. The equivalent megatonnage carried by U.S. heavy bombers *has* declined as older bombers have been retired and the typical payload of those remaining has been changed from a few multi-megaton bombs to a mix of a larger number of lower yield bombs, short-range attack missiles and air-launched cruise missiles.

Currently the United States has about 7,000 warheads mounted on missiles plus a modernized bomber fleet, which by itself carries about 2,000 warheads. The average equivalent megatonnage of U.S. strategic warheads is still about seven times that of the bomb that destroyed Hiroshima [2].

"The Soviets have built the most powerful single weapons ever constructed. Militarily such weapons have very limited value, but as a blackmail threat against free-world cities, they seem to be quite effective."

The Soviets are believed to have 50

Dangerous Myths About Nuclear Arms

By Edward Teller

Educating people about the nature and actual perils of nuclear weapons would not be easy under any circumstances. It is almost impossible when elementary facts are guarded by strict regulations of secrecy. Given such conditions, dangerous myths develop and proliferate.

The reality of nuclear weapons is grim enough. Exaggerations about them are apt only to paralyze us. Some of the current myths have grown from misinterpreted scientific studies; others seem to be based on simple wishful thinking. They all have one common characteristic: so long as they are believed, they obstruct an accurate assessment of our problems and will prevent the development of workable plans to preserve peace.

Myth 1: The Soviet and American nuclear stockpiles are close to identical. A nuclear freeze would stop the arms race and offer improved mutual protection.

Neither the United States nor the Soviet Union publishes information on its current arsenals, and secrecy laws prevent me from discussing even the available estimates. There is, however, an officially released fact: between 1966 and 1981 the total megatonnage of the American nuclear arsenal was *reduced* to less than one-half its former size. The Soviet arsenal has rapidly increased in yield, accuracy and diversity during the same period and currently includes a total nuclear explosive power in excess of what the United States *ever* had.

The Soviets have built the most powerful single weapons ever constructed. Militarily such weapons have very limited value, but as a blackmail threat against free-world cities, they seem to be quite effective. Weapons of such immense size are the most likely to cause damage to the earth's ozone layer (which acts as a shield against lethal amounts of ultraviolet radiation)

Dr. Edward Teller, physicist, was instrumental in the development of the H-bomb, and is currently a Senior Research Fellow at the Hoover Institution at Stanford University.

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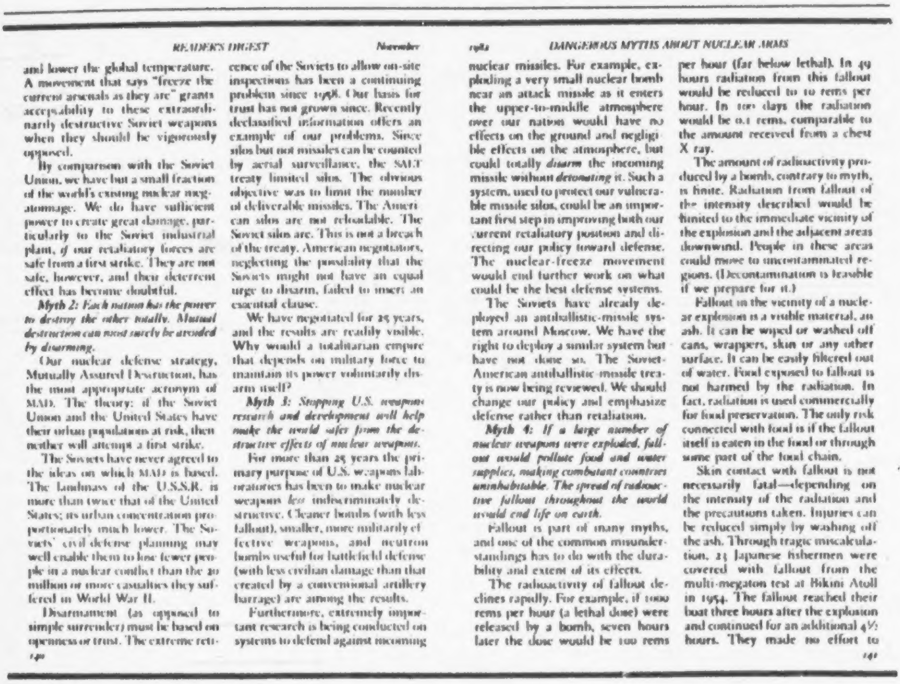

READER'S DIGEST November 1982 DANGEROUS MYTHS ABOUT NUCLEAR ARMS

and lower the global temperature. A movement that says "freeze the current arsenals as they are" grants acceptability to these extraordinarily destructive Soviet weapons when they should be vigorously opposed.

By comparison with the Soviet Union, we have but a small fraction of the world's existing nuclear megatonnage. We do have sufficient power to create great damage, particularly to the Soviet industrial plant, *if* our retaliatory forces are safe from a first strike. They are not safe, however, and their deterrent effect has become doubtful.

***Myth 2:** Each nation has the power to destroy the other totally. Mutual destruction can most surely be avoided by disarming.*

Our nuclear defense strategy, Mutually Assured Destruction, has the most appropriate acronym of MAD. The theory: if the Soviet Union and the United States have their urban populations at risk, then neither will attempt a first strike.

The Soviets have never agreed to the ideas on which MAD is based. The landmass of the U.S.S.R. is more than twice that of the United States; its urban concentration proportionately much lower. The Soviets' civil defense planning may well enable them to lose fewer people in a nuclear conflict than the 20 million or more casualties they suffered in World War II.

Disarmament (as opposed to simple surrender) must be based on openness or trust. The extreme reticence of the Soviets to allow on-site inspections has been a continuing problem since 1958. Our basis for trust has not grown since. Recently declassified information offers an example of our problems. Since silos but not missiles can be counted by aerial surveillance, the SALT treaty limited silos. The obvious objective was to limit the number of deliverable missiles. The American silos are not reloadable. The Soviet silos are. This is not a breach of the treaty. American negotiators, neglecting the possibility that the Soviets might not have an equal urge to disarm, failed to insert an essential clause.

We have negotiated for 25 years, and the results are readily visible. Why would a totalitarian empire that depends on military force to maintain its power voluntarily disarm itself?

***Myth 3:** Stopping U.S. weapons research and development will help make the world safer from the destructive effects of nuclear weapons.*

For more than 25 years the primary purpose of U.S. weapons laboratories has been to make nuclear weapons *less* indiscriminately destructive. Cleaner bombs (with less fallout), smaller, more militarily effective weapons, and neutron bombs useful for battlefield defense (with less civilian damage than that created by a conventional artillery barrage) are among the results.

Furthermore, extremely important research is being conducted on systems to defend against incoming nuclear missiles. For example, exploding a very small nuclear bomb near an attack missile as it enters the upper-to-middle atmosphere over our nation would have no effects on the ground and negligible effects on the atmosphere, but could totally *disarm* the incoming missile without *detonating* it. Such a system, used to protect our vulnerable missile silos, could be an important first step in improving both our current retaliatory position and directing our policy toward defense. The nuclear-freeze movement would end further work on what could be the best defense systems.

The Soviets have already deployed an antiballistic-missile system around Moscow. We have the right to deploy a similar system but have not done so. The Soviet-American antiballistic-missile treaty is now being reviewed. We should change our policy and emphasize defense rather than retaliation.

***Myth 4:** If a large number of nuclear weapons were exploded, fallout would pollute food and water supplies, making combatant countries uninhabitable. The spread of radioactive fallout throughout the world would end life on earth.*

Fallout is part of many myths, and one of the common misunderstandings has to do with the durability and extent of its effects.

The radioactivity of fallout declines rapidly. For example, if 1000 rems per hour (a lethal dose) were released by a bomb, seven hours later the dose would be 100 rems per hour (far below lethal). In 49 hours radiation from this fallout would be reduced to 10 rems per hour. In 100 days the radiation would be 0.1 rems, comparable to the amount received from a chest X ray.

The amount of radioactivity produced by a bomb, contrary to myth, is finite. Radiation from fallout of the intensity described would be limited to the immediate vicinity of the explosion and the adjacent areas downwind. People in these areas could move to uncontaminated regions. (Decontamination is feasible if we prepare for it.)

Fallout in the vicinity of a nuclear explosion is a visible material, an ash. It can be wiped or washed off cans, wrappers, skin or any other surface. It can be easily filtered out of water. Food exposed to fallout is not harmed by the radiation. In fact, radiation is used commercially for food preservation. The only risk connected with food is if the fallout itself is eaten in the food or through some part of the food chain.

Skin contact with fallout is not necessarily fatal—depending on the intensity of the radiation and the precautions taken. Injuries can be reduced simply by washing off the ash. Through tragic miscalculation, 23 Japanese fishermen were covered with fallout from the multi-megaton test at Bikini Atoll in 1954. The fallout reached their boat three hours after the explosion and continued for an additional 4½ hours. They made no effort to

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to 100 missiles carrying single warheads heavy enough to be in the 10- to 20-megaton class [2]. The United States has 52 Titan II missiles carrying comparable (9-megaton) warheads and, in its strategic stockpile, bombs of similar yield designed to be delivered by B-52 bombers [4]. Since the United States has enough lower-yield nuclear warheads to destroy all Soviet cities many times over, these large warheads are being retired by the Reagan Administration.

"The American [missile] silos are not reloadable. The Soviet silos are. This is not a breach of the treaty. American negotiators, neglecting the possibility that the Soviets might not have an equal urge to disarm, failed to insert an essential clause."

Presumably Teller is referring here to the SALT II Treaty whose ratification by the United States he has opposed. If so, his statement is false. The Treaty (Article IV, paragraph 5) explicitly states that both sides will neither "develop, test or deploy systems for rapid reload of ICBM launchers" nor "store ICBMs in excess of normal deployment requirements at launch sites of ICBM launchers."

The only factual basis for Teller's statement is that some Soviet missiles, like the U.S. MX missile, would be ejected from their silos before their engines were ignited ("cold launch") and the silos could therefore be reused. Former Air Force Deputy Chief of Staff for Research and Development, General Kelly Burke, has testified, however, that such reloading would take "on the order of two or three days as about a minimum time. . . . If that area has been struck by our nuclear weapons, then it might not be possible for them to get in at all" [5].

2. The U.S. nuclear deterrent has become doubtful.

"We do have sufficient power to create great damage, particularly to the Soviet industrial plant, if our retaliatory forces are safe from a first strike. They are not safe, however, and their deterrent effect has become doubtful." (Emphasis in original.)

Frank von Hippel is a senior research physicist at Princeton University, Princeton, New Jersey 08544. He is currently the Chairman of the Federation of American Scientists.

Teller is presumably talking here about the "window of vulnerability" popularized by President Reagan and the Committee on the Present Danger. According to their nightmare, the Soviet Union could, in a first strike, theoretically destroy 80 to 90 percent of U.S. missile silos by using two warheads on each silo. It is seldom noted, however, that such a first strike would be more disarming of the Soviet Union than of the United States since on average less than one U.S. warhead would be destroyed for each Soviet warhead expended. (There are on average about two warheads in each U.S. missile silo.)

Furthermore, each of the three legs of the U.S. strategic triad is designed so that it could by itself destroy the Soviet Union. More than 15 U.S. ballistic-missile submarines are always at sea (where they are generally agreed to be invulnerable). These submarines carry about 2,500 warheads, each with two to four times the equivalent megatonnage of the Hiroshima bomb. And the 30 percent of the U.S. bomber force, which is prepared to take off immediately on warning of missile attack, carries about 400 one-megaton bombs plus a similar number of short-range nuclear attack missiles [2].

In addition, the United States has dispersed around the periphery of the Soviet Union hundreds of nuclear-armed land- and carrier-based fighter bombers. These aircraft are capable of reaching the Soviet Union with megaton-sized bombs.

A one-megaton bomb would probably suffice to destroy Moscow. To make sure, Teller would probably insist on several bombs. In either case, it is simply absurd for him to state that the deterrent effect of the thousands of warheads which the United States could deliver on the Soviet Union, even after a Soviet first strike, "has become doubtful." They would deter anyone other than a lunatic, or a government which was convinced that nuclear war was inevitable, from striking first.

3. The effects of nuclear war could be easily mitigated.

"The radioactivity of fallout declines rapidly. For example, if 1,000 rems per hour (a lethal dose) were released by a bomb, seven hours later the dose would be 100 rems per hour (far below lethal). In 49 hours radiation from this fallout would be reduced to 10 rems per hour. . . ."

Unwary readers could be misled by this statement into believing that it would be safe to come out of fallout shelters when the radiation level had fallen to 100 rems per hour. That is not true. Although the dose *rate* at seven hours might be only 100 rems per hour, one would still receive a lethal dose (200 to 600 rems) after several hours outside [6]. Even if one stayed in a shelter for about 49 hours, by which time, as Teller indicates, one would be receiving a dose rate of only about 10 rems per hour, the accumulated dose would still build up to a lethal level after a few days. Indeed, the dose rate of about one rem per hour after two weeks would still be high enough to limit the amount of time one could spend outdoors.

Since ordinary fallout shelters would be less than 100 percent effective in keeping out radiation and would probably provide otherwise very unhealthy conditions, their surviving occupants would have a much reduced resistance to radiation, disease, starvation and the other challenges of the hostile postwar environment [7].

"Radiation from fallout of the intensity described would be limited to the immediate vicinity of the explosion and the adjacent areas downwind. People in these areas could move to uncontaminated regions. (Decontamination is feasible if we prepare for it.)"

One of the few government studies relevant to this question has estimated that an attack on the United States with a megatonnage about equal to that currently in the Soviet strategic arsenal would cover about one quarter of the area of the 48 contiguous states with fallout levels more intense than that discussed by Teller [8].

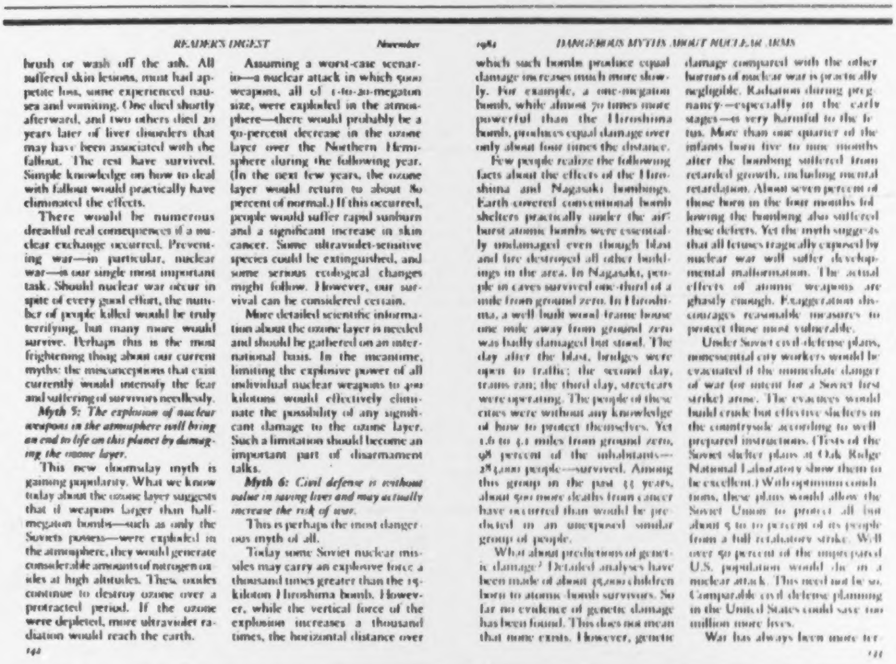
If people took Teller's advice and left their shelters in an attempt to escape such fallout radiation zones, they would be exposed to the full intensity of the radiation field during the period of transit. It is unlikely that in most cases this transit period would be less than hours and, for people traveling on foot, it could be days. It would seem far safer, therefore, to remain inside whatever shelter was available in the fallout zone for at least the first week.

There is nothing in the literature which supports Teller's suggestion that one would be able to decontaminate large enough areas to reduce greatly the risk to the population from fallout.

"Few people realize the following facts about the effects of the Hiroshima and Nagasaki bombings. Earth-covered conventional bomb shelters practically under the air-burst atomic bombs were essentially undamaged even though blast and fire destroyed all other buildings in the area."

Note that Teller does not say that *people* survived, in these "earth-covered conventional bomb shelters." Such a shelter might survive the firestorm which followed the Hiroshima explosion. It is unlikely, however, that its occupants would survive the heat and lack of oxygen.

"1.6 to 3.1 miles [from the ground zeros of Hiroshima and Nagasaki]



brush or wash off the ash. All suffered skin lesions, most had appetite loss, some experienced nausea and vomiting. One died shortly afterward, and two others died 20 years later of liver disorders that may have been associated with the fallout. The rest have survived. Simple knowledge on how to deal with fallout would practically have eliminated the effects.

There would be numerous dreadful real consequences if a nuclear exchange occurred. Preventing war—in particular, nuclear war—is our single most important task. Should nuclear war occur in spite of every good effort, the number of people killed would be truly terrifying, but many more would survive. Perhaps this is the most frightening thing about our current myths: the misconceptions that exist currently would intensify the fear and suffering of survivors needlessly.

Myth 5: *The explosion of nuclear weapons in the atmosphere will bring an end to life on this planet by damaging the ozone layer.*

This new doomsday myth is gaining popularity. What we know today about the ozone layer suggests that if weapons larger than half-megaton bombs—such as only the Soviets possess—were exploded in the atmosphere, they would generate considerable amounts of nitrogen oxides at high altitudes. These oxides continue to destroy ozone over a protracted period. If the ozone were depleted, more ultraviolet radiation would reach the earth.

Assuming a worst-case scenario—a nuclear attack in which 5000 weapons, all of 1-to-20-megaton size, were exploded in the atmosphere—there would probably be a 50-percent decrease in the ozone layer over the Northern Hemisphere during the following year. (In the next few years, the ozone layer would return to about 80 percent of normal.) If this occurred, people would suffer rapid sunburn and a significant increase in skin cancer. Some ultraviolet-sensitive species could be extinguished, and some serious ecological changes might follow. However, our survival can be considered certain.

More detailed scientific information about the ozone layer is needed and should be gathered on an international basis. In the meantime, limiting the explosive power of all individual nuclear weapons to 500 kilotons would effectively eliminate the possibility of any significant damage to the ozone layer. Such a limitation should become an important part of disarmament talks.

Myth 6: *Civil defense is without value in saving lives and may actually increase the risk of war.*

This is perhaps the most dangerous myth of all.

Today some Soviet nuclear missiles may carry an explosive force a thousand times greater than the 15-kiloton Hiroshima bomb. However, while the vertical force of the explosion increases a thousand times, the horizontal distance over

which such bombs produce equal damage increases much more slowly. For example, a one-megaton bomb, while almost 70 times more powerful than the Hiroshima bomb, produces equal damage over only about four times the distance.

Few people realize the following facts about the effects of the Hiroshima and Nagasaki bombings. Earth-covered conventional bomb shelters practically under the air-burst atomic bombs were essentially undamaged even though blast and fire destroyed all other buildings in the area. In Nagasaki, people in caves survived one-third of a mile from ground zero. In Hiroshima, a well-built wood-frame house one mile away from ground zero was badly damaged but stood. The day after the blast, bridges were open to traffic; the second day, trains ran; the third day, streetcars were operating. The people of these cities were without any knowledge of how to protect themselves. Yet 1.6 to 3.1 miles from ground zero, 98 percent of the inhabitants—283,000 people—survived. Among this group in the past 35 years, about 500 more deaths from cancer have occurred than would be predicted in an unexposed similar group of people.

What about predictions of genetic damage? Detailed analyses have been made of about 75,000 children born to atomic-bomb survivors. So far no evidence of genetic damage has been found. This does not mean that none exists. However, genetic damage compared with the other horrors of nuclear war is practically negligible. Radiation during pregnancy—especially in the early stages—is very harmful to the fetus. More than one quarter of the infants born five to nine months after the bombing suffered from retarded growth, including mental retardation. About seven percent of those born in the four months following the bombing also suffered these defects. Yet the myth suggests that all fetuses tragically exposed by nuclear war will suffer developmental malformation. The actual effects of atomic weapons are ghastly enough. Exaggeration discourages reasonable measures to protect those most vulnerable.

Under Soviet civil-defense plans, nonessential city workers would be evacuated if the immediate danger of war (or intent for a Soviet first strike) arose. The evacuees would build crude but effective shelters in the countryside according to well-prepared instructions. (Tests of the Soviet shelter plans at Oak Ridge National Laboratory show them to be excellent.) With optimum conditions, these plans would allow the Soviet Union to protect all but about 5 to 10 percent of its people from a full retaliatory strike. Well over 50 percent of the unprepared U.S. population would die in a nuclear attack. This need not be so. Comparable civil-defense planning in the United States could save 100 million more lives.

War has always been more ter-

98 percent of the inhabitants—283,000 people—survived."

At 1.6 miles from ground zero at Hiroshima and Nagasaki the peak blast overpressure was less than three pounds per square inch and at 3.1 miles the peak overpressure was less than one pound per square inch. These are much lower than the peak overpressures which would be typical in either U.S. or Soviet urban areas during an all-out nuclear war. For the United States it has been estimated that one-half of the urban population would be exposed to overpressures in excess of 15 pounds per square inch [8]. This corresponds to distances of less than one-half mile from ground zero at Hiroshima and Nagasaki—well within the area of total destruction where only a very small percentage of the population survived [9].

4. Soviet civil defense could be highly effective.

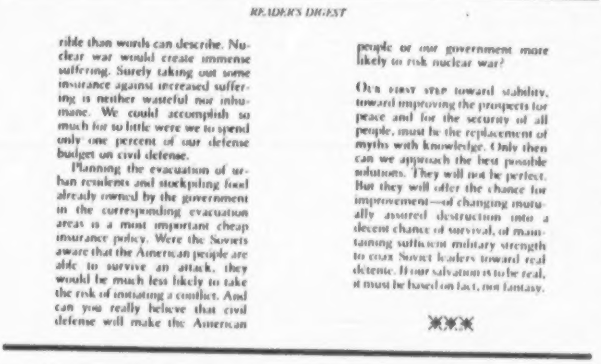
"The landmass of the USSR is more than twice that of the United States; its urban concentration proportionately much lower."

Ur[illegible] population density (people pe[illegible]are mile in cities) has nothing t[illegible]o with national land mass. In fact, because the relative absence of automobiles has allowed much less urban sprawl, the Soviet Union's urban concentration is several times *higher* than that of the United States. Even the Soviet *rural* population is relatively concentrated. One half of it lives in an area about one-tenth as large as that of United States [10].

"Under Soviet civil-defense plans, nonessential city workers would be evacuated if the immediate danger of war (or intent for a Soviet first strike) arose. The evacuees would build crude but effective shelters in the countryside according to well-prepared instructions."

This refers to another of the nightmares popularized by Teller and the Committee on the Present Danger [11]. According to this scenario:

- The Soviets evacuate their cities before a nuclear war. (Much of the



READER'S DIGEST

rible than words can describe. Nuclear war would create immense suffering. Surely taking out some insurance against increased suffering is neither wasteful nor inhumane. We could accomplish so much for so little were we to spend only one percent of our defense budget on civil defense.

Planning the evacuation of urban residents and stockpiling food already owned by the government in the corresponding evacuation areas is a most important cheap insurance policy. Were the Soviets aware that the American people are able to survive an attack, they would be much less likely to take the risk of initiating a conflict. And can you really believe that civil defense will make the American people or our government more likely to risk nuclear war?

OUR FIRST STEP toward stability, toward improving the prospects for peace and for the security of all people, must be the replacement of myths with knowledge. Only then can we approach the best possible solutions. They will not be perfect. But they will offer the chance for improvement—of changing mutually assured destruction into a decent chance of survival, of maintaining sufficient military strength to coax Soviet leaders toward real détente. If our salvation is to be real, it must be based on fact, not fantasy.

⁂

population would have to travel on foot since there are few private automobiles and available buses and trucks would be insufficient to evacuate more than a fraction of the urban population.)

- The evacuees build effective underground fallout shelters using only materials locally available in the fields and forests.
- Each shelter is supplied with a two-week supply of water, food, tools, lanterns, a radiation dosimeter and a radio, plus medical, sanitary and other necessary survival supplies.
- The population stays in these shelters for the two weeks or so required for the intensity of the fallout radiation field to decrease to the point where it would be safe to spend significant periods outside.

It seems likely that at least some of the subscribers to *Reader's Digest* might have become skeptical if Teller had described his nightmare at even this level of detail. Indeed, it appears that he might be suspending his own disbelief since he has apparently not bothered to ask himself how, even if the Soviet population survived for two weeks on emergency supplies, it would survive in the long term with: no fuel for its transportation or agricultural machinery; its farm animals dead from radiation; and its urban housing, factories, hospitals, and distribution systems destroyed. Many of those who have looked at the corresponding problem for the United States after an all-out nuclear war have concluded that the population surviving in the short term would subsequently go into a downward spiral as stocks of food, fuel, medicines, pesticides and critical equipment were exhausted before the capability to replace them could be restored [12].

Of course, evacuation of Soviet cities would eliminate the element of surprise, which would be the principal advantage of a first strike. Upon observing the evacuation, the United States would presumably put its land-based missiles on a launch-on-warning status, send every available missile-equipped submarine to sea and put a much larger proportion of its nuclear bombers and nuclear-capable fighter bombers on a high alert status.

5. Defensive nuclear weapons could protect us.

"Extremely important research is being conducted on systems to defend against incoming nuclear missiles. For example, exploding a very small nuclear bomb near an attack missile as it enters the upper-to-middle atmosphere over our nation would have no effects on the ground and negligible effects on the atmosphere, but could totally disarm *the incoming missile without* detonating *it. Such a system, used to protect our vulnerable missile silos, could be an important first step in improving both our current retaliatory position and directing our policy toward defense. The nuclear-freeze movement would end further work on what could be the best defense systems."* (Emphasis in original.)

Here Teller stakes out his traditional position that continuing the nuclear arms race would be safer than stopping it. He claims specifically that anti-ballistic missiles (ABMs) armed with nuclear warheads may make possible an effective defense for U.S. missile silos. Elsewhere – apparently including a private meeting with President Reagan – he has gone much further and argued that a "third generation" of nuclear weapons might make possible a defense of the *entire nation* against Soviet nuclear attack [13].

Success in the defense of a missile silo can be defined as preventing the attacker from destroying it in a surprise attack without using more warheads than the silo contains. As has been pointed out above (Myth 2), this condition corresponds, for U.S. missile silos, to an average expenditure of two Soviet warheads per silo destroyed and is met today without *any* ABM defense. The additional protection offered by such a defense would probably be quite modest. It is doubtful, for example, whether an ABM system would be effective in defending a silo containing a 10-warhead MX missile against an attack involving 10 Soviet warheads [14].

In any case, defense of the entire nation or even its major cities against nuclear attack would be enormously more difficult than defending hard missile silos. Silo defense requires only having a moderate confidence of preventing up to a few nuclear warheads from coming very close to a silo for long enough to allow launch of its missile. In contrast, city defense requires almost perfect success for the entire duration of the war in keeping thousands of hostile nuclear warheads miles away from targets which themselves cover tens to thousands of square miles. An added complication is the fact that these warheads could be delivered by routes other than through space. Some could even be emplaced in advance, having been shipped as ordinary freight.

6. You can't negotiate with the Soviets.

"We have negotiated for 25 years, and the results are readily visible. Why would a totalitarian empire that depends on military force to maintain its power voluntarily disarm itself?"

The Soviet Union has not, of course, deployed nuclear weapons in order to maintain internal order in its empire. Furthermore, no foreseeable nuclear arms control agreement would come near disarming either superpower. Nevertheless, more limited arms control agreements could reduce the danger of nuclear war and are achievable because they are in the interests of the Soviet Union as well as all other nations.

The arms control negotiations during the past 25 years have not been entirely fruitless. They included the Limited Test Ban Treaty, the Non-Proliferation Treaty, the ABM Treaty and the SALT II Treaty. (The last treaty has been ratified by the Soviet Union but not by the U.S. Senate.) Teller has opposed many if not all of these treaties and has played a leading role in the efforts to prevent the consummation of a comprehensive nuclear test ban treaty. His assignment to the Soviet Union of the full responsibility for the lack of greater success in nuclear arms control negotiations is therefore excessively modest.

Conclusion. For more than 30 years Edward Teller has promised the American public increased security just around the next corner of the nuclear arms race, using arguments such as those put forward in this recent *Reader's Digest* article.

Meanwhile, U.S. immunity to destruction by other nations has been irretrievably lost, and nations such as Argentina, Pakistan and South Africa have moved to the threshold of the nuclear club. Currently the nuclear arms race is pushing the development and deployment of first-strike weapons—a folly which, if not stopped, will lead to hair-trigger, launch-on-warning systems and possibly irreversible deployment of thousands of easy to hide cruise and other mobile missile systems [15]. Adopting Teller's proposal to deploy extensive ABM systems would violate the ABM treaty and would trigger another futile and destabilizing offense-defense race.

There is no foreseeable way in which we can eliminate the existing "balance of terror" by continuing the nuclear arms race. That can only be done by negotiation. Teller's article was apparently motivated by his nightmare that the nuclear weapons freeze movement might force the United States once again into serious arms control negotiations with the Soviet Union. Let us hope that at least this one of Teller's nightmares comes true! ☐

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2. A.A. Tinajero, *U.S./U.S.S.R. Strategic Offensive Weapons: Projected Inventories Based on Carter Policies* (U.S. Congressional Reference Service Report #81-238 F, 1981); Randall Forsberg, "A Bilateral Nuclear Weapon Freeze," *Scientific American* (Nov. 1982), p. 52; Paul H. Nitze, Annex II to statement in "Military Implications of the Treaty on the Limitation of Strategic Offensive Arms and Protocol Thereto (SALT II Treaty)," Hearings before the U.S. Senate Committee on Armed Services, Part 3 (Oct. 1979), pp. 891-914.

3. Robert S. McNamara, "Fiscal Year 1969-73 Defense Program and the 1969 Defense Budget," statement to Senate Armed Services Committee, 1968, p. 57.

4. William M. Arkin, Thomas B. Cochran, Milton M. Hoenig, "The U.S. Nuclear Stockpile," *Arms Control Today* (April 1982), p. 1.

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7. Herbert L. Abrams, "Infectious and Communicable Diseases" in *The Final Epidemic: Physicians and Scientists on Nuclear War*, Ruth Adams and Susan Cullen, editors (Chicago: Educational Foundation for Nuclear Science, 1981), pp. 192-218.

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9. Ashley W. Oughterson and Shields Warren, *Medical Effects of the Atomic Bomb in Japan* (New York: McGraw-Hill), p. 30.

10. U.S. Arms Control and Disarmament Agency, *An Analysis of Civil Defense in Nuclear War* (Washington, D.C.: ACDA, 1978). Quoted in Arthur M. Katz, *Life After Nuclear War* (Cambridge, Massachusetts: Ballinger, 1982), chap. 10.

11. See, for example, "A Method for Dealing with Certain Fallout Questions," attachment to prepared statement of Paul H. Nitze for presentation before the Senate Committee on Foreign Relations, July 12, 1979, reprinted in the *Congressional Record*, July 20, 1979, pp. S1080-81.

12. Sidney Winter, *Economic Viability after Thermonuclear War: The Limits of Feasible Production* (Santa Monica, California: RAND, RM-3436-PR, 1963); Arthur M. Katz, *Life After Nuclear War* (Cambridge, Massachusetts: Ballinger, 1981.)

13. Philip M. Boffey, "Pressures Are Increasing for Arms Race in Space," New York times (Oct. 18, 1982), p. A1.

14. U.S. Congress, Office of Technology Assessment, *MX Missile Basing*, "Ballistic Missile Defense," chap. 3 (Washington, D.C.: U.S. Government Printing Office, 1981.)

15. Harold Feiveson and Frank von Hippel, "The Freeze and the Counterforce Race," *Physics Today* (Jan. 1983), pp. 36-49.

The following exchange continues a debate that was triggered by Edward Teller's article in *Reader's Digest*. The *Bulletin* published Frank von Hippel's "Myths of Edward Teller" in the March issue.

EDWARD TELLER

On facts and hopes

A subject that generates strong emotions also generates strong convictions which are not easily turned around by reason. The March 1983 issue of the *Bulletin* presented a reprint of my article from *Reader's Digest*, "Dangerous Myths About Nuclear Weapons," and an article by Frank von Hippel, "The Myths of Edward Teller." The controversy to which these articles refer has become so heated that it seems helpful to begin by emphasizing a point on which von Hippel and I agree.

Two of the myths I discuss in the *Reader's Digest* article involve scientific matters much misunderstood by the general public: that nuclear weapons will create radiation or damage to the ozone layer sufficient to create an apocalypse. I am gratified that von Hippel offers not one word suggesting that a nuclear war would be the end of the human race.

In my article I call attention to an erroneous idea which by repetition has been elevated to the status of myth: "The Soviet and American nuclear stockpiles are close to identical." The Soviets are currently emphasizing explosives of high megatonnage which are particularly potent as instruments of terror and are the only ones that constitute any danger to the stratosphere. Incidentally, the only thorough analyses of this latter danger have been carried out in the Lawrence Livermore National Laboratory [1-9].

The fact is that the Soviet nuclear striking power is much more potent and reliable than ours. The rough quantitative comparison becomes clearer when one examines the available nuclear military forces item by item. In land-based missiles, the Soviets have a five- or six-to-one advantage in explosive power. For us a first strike is completely excluded, but unfortunately the same cannot be said about the Soviets, who seem to see such a first strike as a preventive measure. A Soviet first strike could completely disarm our land-based missiles.

In bomber forces we are superior. However, both the number of bombers that would be able to take off and, more important, the number that would penetrate Soviet air space is very questionable. While we completely lack air defenses against Soviet bombers, Soviet air defense is practically overwhelming—a fact that will not be changed by putting our bombers on alert following indications of tension or impending attack.

In submarine-carried explosives, we are approximately equal. The general public assumes that submarines are safe from attack. Indeed, the Navy is keeping existing doubts so secret that even many responsible naval officers remain in ignorance about real dangers that may arise from advanced technology in detecting submarines. Even if submarines remain effective, their weapons are targeted against industrial and—regrettably—civilian targets. A force less oriented against military power than against innocent bystanders is adduced by von Hippel as an effective equalizer, but leaves me wishing for a thorough change.

Nuclear war is not inevitable. I do not believe that the Soviet Union will start such a war unless they feel sure of overwhelming superiority and indisputable success. I believe this situation does not yet exist. But the Soviets appear to be superior, and surely are making more rapid progress than we, even at the present time.

Perhaps the most important part of my difference with von Hippel is connected with civil defense. His attitude toward civil defense—which would blunt the effects of nuclear war damage—is particularly hard for me to understand. In view of the possibility of nuclear war, the most urgent and important duty seems to me to be to achieve the best possible preparedness of civilian protection. We must remember that our forces going on alert in case of a Soviet urban evacuation will not save a single American life unless this alert succeeds in deterring war.

Two widely but wrongly held assumptions are present in the accusation that civil defense plans are not effective. The first is that inexpensive shelters cannot be well designed, sanitary and safe to a protection factor of 1,000. They can indeed be so designed and constructed [10]. The second is that the conventional bomb shelters held no survivors in the atomic bombings in Japan. In Hiroshima, an all clear sounded before the bomb was dropped, so there were no people in the shelters. In Nagasaki, the several people in a conventional tunnel shelter *located one-third of a mile from ground zero* survived with minimal or no injury [11].

The idea that Soviet cities would be evacuated, that individual families would build effective underground fallout shelters, have adequate and appropriate supplies and remain in their shelters for a few weeks has a basis in fact and sound planning [12, 13]. Anyone doubtful of the ability of the Soviet transportation system to provide for such an evacuation in a tense situation should examine the Soviet evacuation, not only of personnel but of entire vital industries, which was conducted in 1941 during the fantastic progress of the Nazi invasion.

Radiation is indeed a hazard, and von Hippel in fact does not disagree with my quantitative statements on this topic. It should be noted that while population centers in the Soviet Union could be hit very hard, as von Hippel points out, the greater size of the country and the smaller megatonnage on our side would expose them to a lesser degree of fallout. In fact, this point is indirectly conceded in the discussion of the area that Soviet superbombs would cover with fallout.

It is true that considerable portions of the United States could receive dose rates greater than 1,000 rem per hour in the first few hours after an attack. In a large-scale, civilian-oriented nuclear attack on the United States by the Soviet Union about one-eighth to one-sixth of the United States, primarily the Great Lakes, Ohio River Valley and the East Coast, will sustain levels above lethal values for an *unsheltered* population. Civil defense would clearly be effective in saving many lives in these areas [14]. The structure of the radiation field in space within this area depends on many factors: number and size of explosives per city, clustering patterns from cities, varying wind conditions, presence or absence of rain. These details cannot be predicted in advance and only gross features can be estimated.

Clearly, a dose rate of 100 rem per hour is lethal within a few hours. The main point of the paragraph which von Hippel attacks was to show how rapidly radiation fields decay. I did not advocate that people leave their fallout shelters soon after attack, when radiation levels are high. In a worst-case situation, involving 10,000 megatons being exploded in contact with the ground over the most densely populated one-third of the United States (a somewhat unrealistic scenario), the average radiation in those areas would be 30 to 50 rads* per hour after five days, if no rainful occurs.

Under these worst conditions, people could at that time come out of their shelters for a very short time each day to perform essential tasks. Some areas would have considerably less radiation, and the population could take refuge in these areas at times determined by radiation dose rate and the availability of transportation and supplies. Most importantly, cleanup operations in urban areas where fallout is heavy but blast destruction limited could be conducted for the benefit of whole populations. (Weapons fallout is so composed that vacuuming of streets and sidewalks, possibly by remotely controlled machines, would be effective in lowering the radiation rate.) All this emphasizes the serious need for carefully planned civil defense.

In the final section of his article, von Hippel proposes something new: more negotiations. This suggestion had some novelty a quarter of a century ago. Indeed, the idea is even older. It goes back to the period when Neville Chamberlain, the British prime minister of good will and good intentions, went to Munich with a simple and direct approach to peace and came back with what proved 11 months later to be the complete opposite.

Democracies by their nature will always prefer peace to power. The SALT I Treaty ratified in 1972 did not specify the essential difference between reloadable and non-reloadable silos. Today we know that the Soviet silos are reloadable. The unratified SALT II Treaty tried to rectify this. It is highly doubtful whether, without thorough on-site inspections—which would involve the effective breakdown of the Soviet police state—this deficiency can actually be changed.

There is one final point of agreement. We live in dangerous times with many hazards, deadly not to the human race but to countless individuals and, what is even more important, to the human spirit. In this situation, von Hippel, I and every sane individual agree that we must attempt not only to prevent nuclear war but any war. The disagreement involves not our aim but the practical execution of this aim.

For years, I have tried to counteract the consequences of neglecting military technology in the United States, the consequences of negotiations governed by hopes for "peace in our time" and the results of badly divided counsel. Recently yet another erudite and gifted writer has offered this comment about scientific experts: "All they can tell us is what the weapons are" [15]. In view of past and accelerating developments of weapons technology there is clearly the possibility for technologists to make informed guesses about future weapons which could have surprising and (contrary to widespread opinion) not invariably harmful results. It is regrettable that in our schizophrenic world of two cultures, nontechnical discussions presume without argument that technology has either a static or a steadily more perilous nature. Help could be provided, but if only the rules of secrecy would permit it. Without this permission we face not only a "window of vulnerability" but an abyss whose depths cannot be guessed.

I have long struggled with the problem. Due to the initiative of brilliant young people, I have discarded many of my old opinions and have come to hope for *defensive* nuclear weapons directed against the instruments of war in action rather than against people. I was recently informed that at last I may assert my interest in x-ray lasers, but not my evaluation of whether these can have a place in a defensive arsenal.

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*The difference between rads and rem (which arises because this information was drawn from two different sources) is unfortunately smaller than the uncertainty of any estimate of radiation levels.

Frank von Hippel is the grandson of James Franck, a giant in physics with an understanding heart, who was my mentor and dear friend. A few months ago, I spoke in Chicago at the centennial of his birth. If he and his grandson had been present, perhaps jointly we could have accomplished more than a printed and repetitious controversy. ☐

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2. J.B. Knox and others, "Program Report for FY 1980," Atmospheric and Geophysical Sciences Division of the Physics Department, UCRL-51444-80.

3. J.B. Knox and others, "Program Report for FY 1979," Atmospheric and Geophysical Sciences Division of the Physics Department, UCRL-51444-79.

4. W.H. Duewer, B.J. Wuebbles, J.S. Chang, "Effects of a Massive Pulse Injection of NO$_x$ into the Stratosphere," UCRL-80397 (April 1978).

5. Fred M. Luther, "The Ozone Layer: Assessing Manmade Perturbations," *Energy and Technology Review*, UCRL-5200-78-1 (Jan. 1978).

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14. T.F. Harvey, "Influence of Civil Defense on Strategic Countervalue Fatalities," UCID-19370, Lawrence Livermore National Laboratory (April 28, 1982).

15. Leon Weiseltier, "The Great Nuclear Debate," *New Republic* (Jan. 10, 17, 1983), pp. 7-35.

* * *

Frank von Hippel's response: In Edward Teller's reply to my critique, he does not defend any of the many claims that I showed to be either misleading or false in his *Reader's Digest* article. Instead, he offers nine references to studies on the effects of nuclear explosions on the Earth's ozone layer and five on the effectiveness of subsurface shelters against radioactive fallout.

As Teller acknowledges, his first set of references documents a point in his article that I did not challenge; that is, that a high-yield nuclear explosion set off at the Earth's surface is a much greater threat to the ozone layer than a number of smaller surface bursts with the same total yield. The reason is quite simple: the larger fireball will rise farther into the sensitive layer of the stratosphere.

The references on fallout shelters are also not germane to my principal criticism of Teller's discussion of the value of civil defense in an all-out nuclear war. I did not question that, given the time, transportation, supplies and equipment, and favorable conditions, a well-trained populace could build fallout shelters effective enough to allow survival for a few weeks in areas not directly targeted with nuclear weapons. I did challenge, however, Teller's implied equation of such short-term survival with the long-term survival of the populace of a modern nation whose industrial and transportation systems had been subjected to large-scale nuclear attacks. Teller has not responded to this fundamental criticism.

As far as the future of the nuclear arms race is concerned, the most important issue raised by Teller's *Reader's Digest* article is his claim that "the deterrent effect [of U.S. nuclear forces] has become doubtful." In my critique, I argue that such a statement is indefensible because no first strike could reduce our deployed arsenal of many thousands of protected and deliverable strategic weapons to a size that is less than terrifying. While, in his reply, Teller expresses (in my view greatly exaggerated) concerns about the vulnerability of U.S. strategic forces, I am pleased to note that he comes nowhere near reasserting his original claim.

Finally, I would like to make a point about the importance of secret information in the formulation of public policy concerning nuclear arms. Teller's *Reader's Digest* article began as follows:

> "Educating people about the nature and actual perils of nuclear weapons would not be easy under any circumstances. It is almost impossible when the elementary facts are guarded by strict regulations of secrecy."

In fact, I believe that my critique and Teller's response show that all of the "elementary facts" — true and false — asserted in his article can be checked, using only information available in the public domain.

Indeed, Teller has indicated only one very limited area, relating to the discussion of x-ray lasers, where he has felt restrained by secrecy regulations. Even here, however, the promoters of the technology found a way around the censors. A relatively detailed description, complete with an artist's conception, of the hopes of these scientists (apparently including Teller) for an anti-ballistic missile system in space based on nuclear explosion-powered x-ray lasers, may be found in an article published in the February 23, 1981 *Aviation Week and Space Technology*. ☐

The scientific community has been interested for many years in the potential consequences of nuclear war. We commend the reader to the materials which we have included in the bibliography in our appendix to these views, and we would also particularly suggest the following publications; "Long-Term Worldwide Effects of Multiple Nuclear Weapons Detonation," National Academy of Sciences, Washington, D.C., 1979; "The Effects of Nuclear Weapons," edited by Samuel Glasstone and Phillip Dolan, U.S. Departments of Defense and Energy, Government Printing Office, 1977; and, "Soviet Civil Defense," a report issued by the Director of Central Intelligence, Bureau of Public Affairs, Office of Public Communications, Washington, D.C., July 1978.

While these materials are not exhaustive of the scientific data available on the questions of the consequences of nuclear war, they should be sufficient to point out to the reader that the issue is one which deserves, and which has received a far more exhaustive, and far more scientific analysis than that which appears in the body of this report. One article which we believe should be brought to the attention of those interested in this issue appeared in the May, 1981 issue of The Bulletin of the Atomic Scientists, which was entitled "Surgical Problems Among the Survivors." This article, written by John D. Constable, M.D., who is associate clinical professor of Surgery at Harvard Medical School, visiting surgeon at the Massachusetts General Hospital, and chief consultant in plastic surgery at the Shriners Burns Institute in Boston, is particularly relevant to the issue of immediate medical consequences of a nuclear explosion, and we therefore have included the article in our views at this point in its entirety.

Remarks from a symposium organized by the Council for a Livable World Education Fund and the Physicians for Social Responsibility on 'The medical consequences of nuclear weapons and nuclear war.'

JOHN D. CONSTABLE

Surgical problems among survivors

The crash of a partially filled 30-passenger airplane on Nantucket Island required the mobilization of all the emergency medical facilities of Greater Boston, a major surgical center. Yet we are seriously asked to contemplate and to discuss the possibility of ten thousand or a hundred thousand or even a million severely traumatized victims of a military nuclear explosion.

These numbers could be so matter-of-factly proclaimed only by those who are in complete ignorance as to the possibility of any adequate or even partially adequate medical treatment being made available to such survivors. As medical facilities are now set up, we can talk about how such injuries *should* be treated, but to transfer this knowledge to the practical possibilities of the treatment of the numbers of victims that have been predicted is categorically out of the question.

The injuries caused by a massive nuclear detonation would come from the various effects of such an explosion. Although I will briefly consider a number of different injuries, I would like to point out at once that burns or thermal injuries would be by far the most crushing burden on the available medical resources. In the case of very large explosions, radiation levels sufficient to cause immediate—or only very shortly delayed—death or massive radiation damage can be expected to extend not very far beyond the zone of lethal damage due to heat or blast. With relatively smaller explosions, such as those used in Japan, this is not strictly true. But it still means that among the survivors of an explosion of the size currently contemplated there would not be very many patients who might die soon from the immediate radiation effects.

The direct blast of a nuclear bomb will, of course, result in a number of injured survivors, but we must keep in mind that the explosion is relatively much more destructive to buildings than it is to persons. Whereas most ordinary houses are destroyed by an increase of perhaps five pounds per square inch in atmospheric pressure, the human body, as long as it is protected from injury by other objects, can stand a temporary increase of 30 to 50 pounds per square inch.

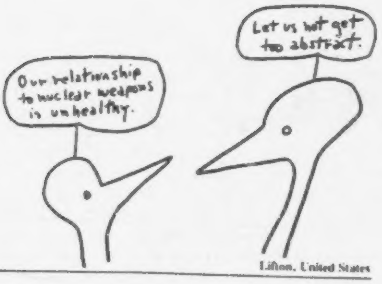
There will, however, be very extensive traumatic injury to people within and around buildings, as a result of being blown out of them and by being damaged by debris from the destruction around them. Also, the initial blast effect of the explosion is characteristically followed by very powerful local winds rising to as much as 100 or 180 miles per hour and these, of course, will cause a number of severe traumatic injuries.

Most of those injured, whether they have been crushed, cut, or blasted, but who have survived initial injury and have reached adequate medical facilities would, in most cases, be expected to require only one major surgical procedure. Although this might be very expensive in terms of time and material, including a great deal of blood and other support, the victims could then in most cases be expected to enjoy a relatively uncomplicated convalescence. The non-nuclear war experience in Vietnam has taught us that, at least among younger patients, even the most severe intra-abdominal or thoracic injuries, whether resulting from bombs, shellfire, or other causes, can be restored fairly quickly provided that the patient can survive until a medical facility has been reached and that major restorative procedures could then be carried out.

Of all the trauma resulting from a nuclear explosion, thermal injuries, even though heat and light contain only some 35 percent of the total energy of such an explosion, are first and foremost in terms of the extent of medical treatment needed in the first few weeks of injury. But, somewhat paradoxically, even though burn victims end up by consuming vastly more of the medical facilities than other injuries, most of those surviving burns can, in fact, be transported with minimal treatment for the first eight to 24 hours after the injury.

Some special aspects of the burn problem need to be considered. How important is carbon monoxide poisoning? In an outdoor fire significant poisoning from this source is usually rare. Even when it occurs in a patient exposed to carbon monoxide in a confined space, either the levels of blood saturation have become so high that there is irreversible anoxic brain destruction, in which case there will be no recovery; or by the time the patient reaches a medical facility spontaneous recovery will be sufficiently advanced that the residual carbon monoxide absorbed will not be a major problem in treatment.

Patient anoxia resulting from most of the atmospheric oxygen having been used up by a fire—theoretically important in a so-called fire storm—is clinically rare. If the degree of thermal activity is sufficient to cause anoxic


Our relationship to nuclear weapons is unhealthy.
Let us not get too abstract.

Lifton, United States

damage, then there will usually be concomitant fatal incineration. But if there is only a relative degree of anoxia, spontaneous recovery will occur by the time the patient has reached a medical facility.

Both carbon monoxide poisoning and fire induced anoxia must be distinguished from so-called pulmonary burns, which remain one of the major largely unsolved therapeutic problems of thermal damage. This is a form of lung injury which usually takes from 24 to 72 hours to develop and is not, in fact, the result of direct thermal damage to the lung. If the heat around the patient's face is sufficient to result in actual destruction of the trachea, bronchae, or lungs, there will almost invariably be such devastating destruction of the face and other parts of the skin as well that the patient will not survive.

It is now generally accepted that the damage to the lungs is a result of the chemical activity of noxious products of incomplete combustion. Consequently, this type of burn is characteristic of fires in closed spaces rather than the open spaces which would be more common with a major bomb. Among people confined to buildings, pulmonary burns will be a major lethal factor. In the Coconut Grove fire in Boston some 40 years ago, over 400 people died, almost all without visible signs of burns. These deaths, which occurred mostly two, three and four days after the fire, resulted from pulmonary damage now believed to have been from the fumes from the plastic in the artificial palm trees and furniture coverings.

Although pulmonary damage may be a major cause of death in burns, it must also be recognized that this aspect of thermal damage does not really pose an immense burden on triage or on the medical system. This is because, even with the best possible facilities, it remains essentially untreatable. In general, these patients either have so major a lung injury that they will die, or with a relatively lesser degree of injury they will spontaneously recover quite quickly.

Aside from these secondary aspects, there will be two kinds of direct thermal injury from a nuclear explosion: one will result directly from the detonation; the other from the secondary fires following the ignition of available combustible material. These secondary fires are of at least two sorts. One is the possibility of a fire storm, and with the lower concentration of combustible materials in American towns and cities this is a little less likely than in many other parts of the world. Much more certain is the development of a major conflagration which would be essentially the sort of fire with which we are all too familiar, but enormously increased in scale. This fire would, of course, be associated with multiple smaller ones, starting from the breaking of gas mains, the failure of electrical pumps, the lack of water to put them out, and so on. The fires would presumably be spasmodic over a very large area.

Patients would thus be exposed to the risks of thermal damage from the bomb itself and from its secondary fires. I believe that there is no essential difference in the nature of burns resulting from these two etiologies. Burn damage to the skin results from a combination of the amount of heat and the time of exposure, these factors being very much modified by the presence or absence of clothing, the moisture content of the atmosphere, and other factors. An explosion results in an almost instantaneous exposure to a very high heat level with damage occurring over an incredible distance; but the nature of the injury is not, I think, different from other forms of thermal burns. It simply means that there can be much more severe damage in a very short time if the heat to which one is exposed is very great.

I must at least mention the problem of thermal injuries combined with the effects of radiation. All patients seriously injured by nuclear explosion who have also had a significant amount of radiation injury will be more difficult to treat. My assumption here is that relatively few surviving patients will have received sufficient radiation to result in death within a matter of weeks or months from the radiation alone. But even with those who have received smaller doses of radiation, the damage to the immune system and to blood element regeneration results in the patient being more prone to invasive sepsis, in less satisfactory healing, and in an increased risk of death from a thermal injury which might otherwise not have been fatal.

Experimental studies have shown that a burn from which a normal animal can be expected to recover becomes lethal if the animals have been previously or concomitantly exposed to non-lethal radiation. (A medically interesting note: in dealing with a very small number of victims, as in a nu-

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clear reactor explosion, the immunosuppressive aspects of radiation might not be totally disadvantageous. In current practice, severely burned patients are treated by immunosuppression in order to allow for the extensive use of allografts.)

First degree burns are at their very worst equivalent to a severe sunburn. They may result in some transient dehydration, certainly considerable pain, but under any emergency conditions, these require essentially no treatment and must be considered of no particular medical consequence.

Second degree or partial thickness burns (the latter term is much to be preferred) are, from the point of view of the immediate surgical problems, almost as severe an injury as are full thickness burns. A deep partial thickness burn requires essentially the same amount of resuscitative effort, the same difficult nursing, the same elaborate dressings, and the same extensive care during the first three to four weeks. Although these injuries heal from the base and therefore no skin grafting is required, and the eventual problems of resurfacing the patient are a great deal simpler, the immediate problem of care is almost as great as with a full thickness burn. The two groups should be combined from the point of view of trying to evaluate the early load on the medical system.

It is very difficult to estimate accurately the extent and number of burn survivors in a population exposed to a nuclear explosion. The figure might vary by as much as a thousandfold, depending upon specific factors prevailing at the time of the explosion. These include not only the size of the bomb and the above ground level of the explosion, but also the atmosphere. Even a moderate degree of opacity in the air strikingly reduces the range of thermal damage. Other factors include the season, the time of the day, and the extent to which the population has been pre-warned. These conditions partly determine the amount of clothing being worn and whether people are outdoors or not, since at the periphery of an explosion protection from, or at least reduction of, the extent of thermal injuries can be fairly easily obtained.

Even with these caveats and modifiers, it has been estimated that for a one-megaton nuclear explosion, with ten-mile visibility, only first degree burns might be expected within a seven-mile radius; second degree or partial thickness burns within a six-mile radius; full thickness destruction within five miles. If the atmosphere were sufficiently opaque to reduce visibility to two miles, then the second degree zone would be reduced from six miles to something under three and the others changed proportionately.

The two-and-a-half mile radius from the center of the explosion—the limit of second degree burns if the atmosphere restricts visibility to two miles—is approximately the same limit as that of five pounds per square inch of blast. This is generally considered to be the lethal average for humans, due to secondary effects of blast and wind, so it becomes clear that unless the atmosphere is even more opaque, the greatest number of severely damaged survivors will be within two-and-a-half to six miles from the center and their trauma will be the result of thermal injury rather than other causes.

Unfortunately, this is the form of trauma which demands the largest amount of medical assistance if it is properly managed. There is, indeed, no injury that can be counted on to use up more hospital facilities than can a severe burn. Triage—judging which burn patients will survive—would be very difficult and it may be necessary to treat a great many patients for extended periods who will eventually die from their injuries.

The burn literature has been filled over the last ten years with reports of progress in salvaging the severely burned. Many new methods of infection control have come into use, including various surface antiseptic agents and topical antibiotics. The surface control of infection has prevented the conversion of partial thickness to full thickness burns by sepsis and has strikingly improved overall results in burn salvage. There has also been much effort to control systemic infection, both by the use of antibiotics and by elaborate isolation techniques. There are life islands in which patients are more or less isolated in a plastic enclosure, and more recently laminar flow units. These latter are devices in which the air is regularly replenished and replaced so that bacteria are swept away and the air is kept essentially sterile. All of these methods have helped reduce death from infection.

Another recent development is the early surgical excision of burns. This is now often done, and although it is usually not safe to excise more than one-fifth of the patient's body surface at one sitting, surgery may be carried out on the first or second day after burn, and with maximum support again on the fourth, and so on, ending with as much as 80 to 90 percent of the skin being excised. Massive excision has been combined with immunosuppression so as to allow for the use of typed allografts taken from living donors or cadavers. It is possible with these methods to obtain some dramatic results although they are still cosmetically or aesthetically relatively grotesque. These are certainly very satisfying to the burn surgeons involved, and reasonably so, perhaps, to the patients and their families.

It is absolutely essential to recognize, however, that any really severe burn that is salvaged may require as many as 30 to 50 operative procedures, both immediate and delayed, and months and months of hospitalization. This imposes immense strains on the medical facilities available. With the newer and more dramatic methods,

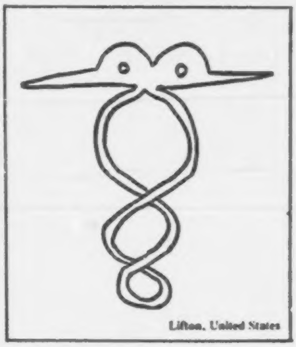
The Physicians for Social Responsibility and the Council for a Livable World Education Fund have collaborated in the organization of the Conferences on the Medical Consequences of Nuclear Weapons and Nuclear War. These conferences have been held in Cambridge, Mass., New York City, San Francisco, Calif., and Seattle, Wash. The next conference is to take place in Chicago on June 19 and 20. For information, call the Council at 617-742-9395.

there is at least the possibility, if sufficient material and personnel are poured in, of salvaging burns in the 85 to 90 percent range.

This, of course, makes triage much more difficult. We would be faced with an enormous group of patients sustaining 20 to 90 percent burns who might survive if treated. Except for localized burns of the hands and face, I exclude burns affecting under 20 percent of surface, because most of these can be relatively easily treated. What is, in fact, involved, in the possibility of treating large numbers of severe burns?

Some years ago the Shriners of North America, who had for years donated large sums to look after orthopedically crippled children, began to have less orthopedic demand because of diminishing polio, tuberculosis, and chronic osteomyelitis. They therefore became interested in building specialized burn hospitals for children. Their plan was to start with three burn units and then expand, possibly adding another 15 or so to match the number of orthopedic hospitals they were already maintaining. These initial three units were built in Boston, Galveston, and Cincinnati. In the 15 years since these three 30-bed hospitals were built, it has not been practicable to build even one other unit, because the three burn units, with a total of 90 beds, use up a budget similar to that of nineteen orthopedic hospitals, most of which are of comparable size.

The cost of running a single 30-bed hospital, in which half of the beds are reconstructive and where there would rarely be more than ten acute burn cases at one time is in the neighborhood of $4 million per year. There are, all over the United States, something like one thousand so-called burn beds. These are in specialized institutions willing to look after severe burns, but to do this appropriately each burn patient requires specialized individual nursing for quite a long time.



Lifton, United States

At most, one nurse can look after two patients.

Severe burn cases require not just one major operation, but may need general anesthesia every other day and regular trips to the operating room for weeks or even months. There are elaborate dressings and the application of appropriate antibiotics or at least antiseptic agents. The patients require large amounts of blood, albumin, and other human blood derivatives. They may need enormous areas of allografts, and even in wartime it may be difficult to obtain sufficient quantities of these from cadavers.

Whereas most traumatic lesions are more or less definitively treated immediately, and the victims either recover or die, burns are peculiar. The burn patient is not so ill during the first 12 to 24 hours. I have seen a number of older patients with 40 to 50 percent full thickness, clearly fatal, burns who, for the first 12 to 24 hours after their injury, appeared in reasonably good condition. They were capable of consulting their lawyers and doing whatever needed to be done. It is after this initial period that the patient becomes sicker and sicker, and this critical hovering between survival and death may go on for weeks or months. Then, once a burn has been initially resurfaced, it may need months or years of reconstruction. And even with all of this, anyone who is discriminating or humane would recognize that the end results are indeed pathetically poor.

It is very difficult to estimate the cost of such cases in dollars because, to the best of my knowledge, no health program or insurance pays adequately for burn care. Blue Cross/Blue Shield and similar programs admit that they cannot afford to pay the true cost. Nonetheless, it is reasonable to put the cost at anywhere from $200 to $400 thousand for the average severe surviving burn case.

Even though there are 30-bed burn units, such as the Shriners' or those at large general hospitals, they can, in fact, handle only two or three fresh severe burns at once. If there is a large group of such burns in a major accident, they will have to be distributed for any effective treatment.

Even the most famous burn disasters of recent years—the Coconut Grove, plane crashes, or the Hartford Circus—have resulted in very few initially surviving major burns, but the expectation of any holocaust, such as a nuclear bombing, is that there will be at least thousands of severely burned people immediately surviving. The most conservative calculation of the thermal injuries resulting from an isolated one-megaton or "minimal nuclear explosion," with preservation of all U.S. medical facilities and the availability of immediate and perfect triage and transportation, will completely overwhelm what we consider to be one of the most lavish and well-developed medical facilities in the world. It is impossible to imagine the chaos that would result from a larger explosion in which the hospitals themselves were partially destroyed and there was no ability for significant triage or intercenter transportation. The medical facilities of the nation would choke totally on even a fraction of the burn casualties alone. ☐

We feel strongly that the best possible deterence to a nuclear war is a full and complete understanding of the catastrophic consequences of nuclear war. World leaders and private citizens should, and must know exactly how terrible those consequences would be. But, we must guard against presenting any data on those consequences in unbalanced ways, or in ways designed to manipulate public fears merely for political purposes. An excellent study which appeared in the July, 1979 issue of "Scientific American," by Kevin N. Lewis is included in these views at this point because we feel it presents much of the scientific data in a factual way, without polemics, and without the hyperbole in the Committee Report.

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The Prompt and Delayed Effects of Nuclear War

The prompt effects of nuclear weapons are the basis for the size of U.S. strategic forces. The delayed effects are equally great, ensuring that these forces remain a more than ample deterrent

by Kevin N. Lewis

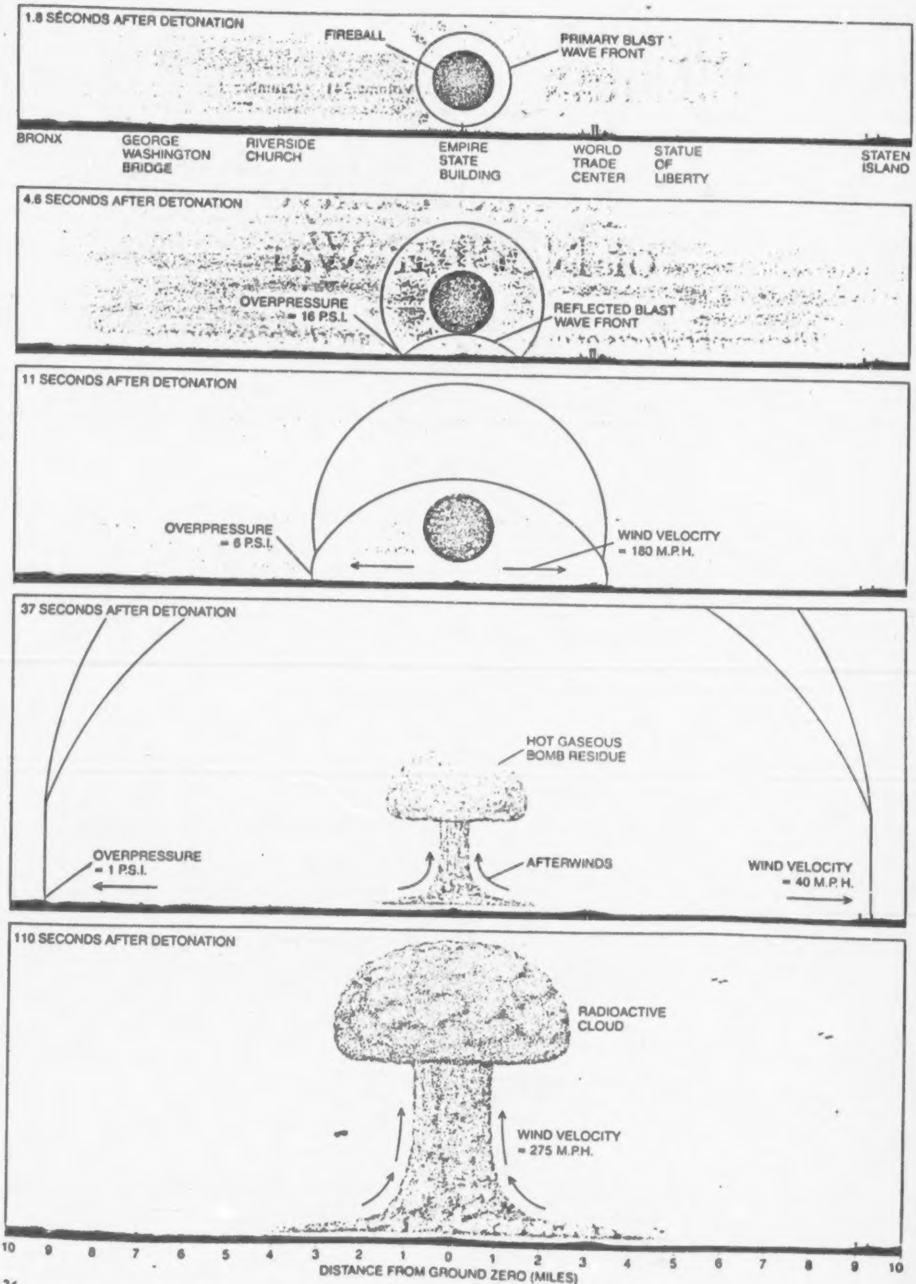
The primary purpose of this country's strategic nuclear forces is to deter the U.S.S.R. from launching an attack on the U.S. or its allies. To accomplish that mission the U.S. maintains the constant ability to inflict intolerable damage on the U.S.S.R. The long-range missile and bomber forces of the U.S. have been designed to survive even an all-out surprise attack by the U.S.S.R. in numbers sufficient to deliver a devastating retaliatory counterattack. Since the U.S.S.R. has similar forces, it is considered unlikely that either side would find it advantageous to attack the other. It is this mutual retaliatory potential, or assured-destruction capability, that is widely held to be responsible for the strategically stable military balance between the two superpowers.

Since in this view the avoidance of war depends in part on the integrity of the assured-destruction capability of the U.S., any degradation of that capability would be a grave matter. Accordingly recent assertions by some military analysts that the U.S.S.R. is actively pursuing measures to reduce the effectiveness of an American retaliatory strike have given rise to much concern. Specifically it is alleged that ambitious Russian civil-defense initiatives could create a dangerous strategic asymmetry in the absence of countervailing U.S. efforts. For example, in conjunction with a surprise "counterforce" attack on U.S. land-based missiles the U.S.S.R. could attempt to evacuate its cities, with the projected result that Russian fatalities in an all-out nuclear exchange would be substantially fewer than American ones. In such a situation the U.S. might be inhibited from further escalating hostilities, and the U.S.S.R. would then in various ways be able to impose its will. Even if all-out war were to ensue, the U.S.S.R., it is said, would be able to recover much faster than the U.S. One result of this line of reasoning has been a revival of interest in the moribund American civil-defense program; another has been the consideration of new strategic-missile targeting options designed to defeat the Russian civil-defense program.

Such hypothetical scenarios are based in part on underestimates of the damage the surviving U.S. forces could inflict on the U.S.S.R. Many estimates of this kind include only the easily calculable blast effects of nuclear weapons. They ignore the equally devastating effects of thermal radiation and ionizing radiation. When these additional effects are included in the calculations, it is clear that nuclear war remains an unmitigated mutual disaster, and that no conceivable civil-defense preparations could materially change the prospect. Therefore from an operational military point of view there is no validity to assertions that the U.S. retaliatory capability is "eroding." Moreover, it is extremely unlikely that the situation will change in the foreseeable future.

How is the damage from nuclear war estimated, and what consequences of such a war are routinely excluded from calculations of the damage? In this article I shall compare calculations frequently used to assess "adequate" levels of assured destruction with estimates of the probable wider results of a nuclear exchange between the two superpowers. The more comprehensive analysis shows that neither the U.S. nor the U.S.S.R. needs to be concerned about the integrity of its retaliatory capability. Although much of the current debate on the gravity of the Russian threat tends to ignore this fact, there can be no conceivable doubt that all-out war remains a losing proposition for both sides. Credible deterrence of course relies on many factors other than the ability to conduct a massive retaliatory attack. It is in the interest of all parties, however, that the notion of "winning" an all-out nuclear war, in the sense of one side's being able to improve its relative position at an acceptable cost, be dismissed from the strategic debate, and that the full consequences of such a calamitous event be brought to public attention.

Specific criteria of retaliatory effectiveness were first established under the direction of Secretary of Defense Robert S. McNamara in the early 1960's. Up to that time strategic military planners lacked any formal quantitative standards for determining the appropriate levels of U.S. retaliatory forces. Secretary McNamara therefore advanced the concept of assured destruction, arguing that the destruction of between 20 and 25 percent of the U.S.S.R.'s population and at least 50 percent of its industrial capacity would constitute unacceptable damage in the eyes of that country's leaders. By establishing these measures McNamara was better able to coordinate Air Force and Navy planning, to match strategic military requirements with existing force structures and to eliminate programs that were superfluous. Although the task of defining a certain level of damage had a political purpose, namely to threaten the government of the U.S.S.R. with intolerable de-


1.8 SECONDS AFTER DETONATION
FIREBALL
PRIMARY BLAST WAVE FRONT
BRONX
GEORGE WASHINGTON BRIDGE
RIVERSIDE CHURCH
EMPIRE STATE BUILDING
WORLD TRADE CENTER
STATUE OF LIBERTY
STATEN ISLAND
4.6 SECONDS AFTER DETONATION
OVERPRESSURE = 16 P.S.I.
REFLECTED BLAST WAVE FRONT
11 SECONDS AFTER DETONATION
OVERPRESSURE = 6 P.S.I.
WIND VELOCITY = 180 M.P.H.
37 SECONDS AFTER DETONATION
HOT GASEOUS BOMB RESIDUE
OVERPRESSURE = 1 P.S.I.
AFTERWINDS
WIND VELOCITY = 40 M.P.H.
110 SECONDS AFTER DETONATION
RADIOACTIVE CLOUD
WIND VELOCITY = 275 M.P.H.
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10
DISTANCE FROM GROUND ZERO (MILES)

struction, the specific percentages chosen reflected the capabilities of the U.S. strategic forces programmed at that time. The required levels of destruction were also based to some extent on the characteristics of the particular target system represented by the U.S.S.R.

The population and economic resources of the U.S.S.R. are concentrated in a remarkably small number of major urban centers. About a third of the population and nearly two-thirds of the industrial capacity are concentrated in the country's 200 largest cities. Nuclear attacks on additional cities would not appreciably increase the retaliatory damage (except for the delayed effects of radioactive fallout). McNamara's criterion of assured destruction could therefore be loosely translated into the ability to destroy the 200 largest cities in the U.S.S.R.

Given this assumption, U.S. force requirements could be set by determining the number of nuclear warheads needed to destroy the social and economic targets of importance in those 200 cities. Target planning is sensitive to many operational factors, such as the composition and layout of cities, but above all it calls for predicting accurately how the local population will be affected by the lethal effects of nuclear explosions. In actual practice retaliatory damage is predicted by matching the physical properties of nuclear explosions with the relevant target characteristics on a city-by-city basis. In calculating such damage levels U.S. planners have at their disposal a large store of information on each target, sophisticated analytical techniques and an advanced data-processing capability. The results of these detailed calculations can be approximated fairly well, however, with the aid of some simple procedures.

The yield of a nuclear weapon is usually described in terms of the quantity of chemical explosive required to release an equivalent amount of energy; a nuclear weapon is said to have the power of kilotons (thousands of tons) or megatons (millions of tons) of TNT. As in a chemical explosion, the energy from a nuclear explosion is generated very quickly in a small volume. When the nuclear explosion is set off in the air, the energy released instantaneously vaporizes the components of the warhead, creating a hot, rapidly expanding fireball. The explosion gives rise to two prompt effects that in an attack on a city can be devastating. First, as the fireball expands it sends a shock wave through the surrounding medium. The shock wave, which travels away from the point of the explosion at supersonic speeds, does blast damage to structures and people. The hot fireball also radiates thermal energy, mainly photons in the visible and infrared regions of the electromagnetic spectrum, which can cause burns and ignite materials that are not protected by some kind of opaque screen. Roughly half of the weapon's energy is eventually converted into mechanical blast motions and about a third is released in the form of thermal radiation. The rest of the energy is represented by prompt nuclear radiation and delayed thermal and nuclear radiation, none of which are treated as being important in assured-destruction planning but all of which nonetheless add to the destructiveness of a nuclear attack.

The mechanical motions of a nuclear explosion are analogous to those of a tidal wave. The shock front is literally a wall of compressed air. As it passes, structures are exposed to a nearly instantaneous rise in the local atmospheric pressure, and they may be crushed. Following the shock front are strong winds analogous to the water currents that follow a moving ocean wave. The forces resulting from these winds may also lead to the collapse of structures in the target area. Depending on their shape and construction, buildings may be vulnerable either to the shock wave or to the winds that follow it or to both. The "hardness" of a target (its ability to withstand the destructive effect of the shock wave) is generally described in terms of the induced peak "overpressure" (in pounds per square inch above atmospheric pressure) at which the target is destroyed.

Thermal radiation can lead directly to flash-burn casualties and indirectly (through the ignition of nearby materials) to flame-burn casualties, superposing both effects on blast casualties. The extent of such damage depends on both the power of the radiant energy delivered (usually measured in calories per square centimeter) and the period over which the energy is delivered. Destructive blast effects decay with distance faster than thermal effects. Therefore under ideal conditions a nuclear explosion can do substantial incendiary damage well beyond the area devastated by blast. The thermal damage, however, is much influenced by external factors, including the presence of clouds or of snow cover, the relative transparency of the atmosphere and the composition of the target. Hence thermal effects are far less predictable than direct blast effects.

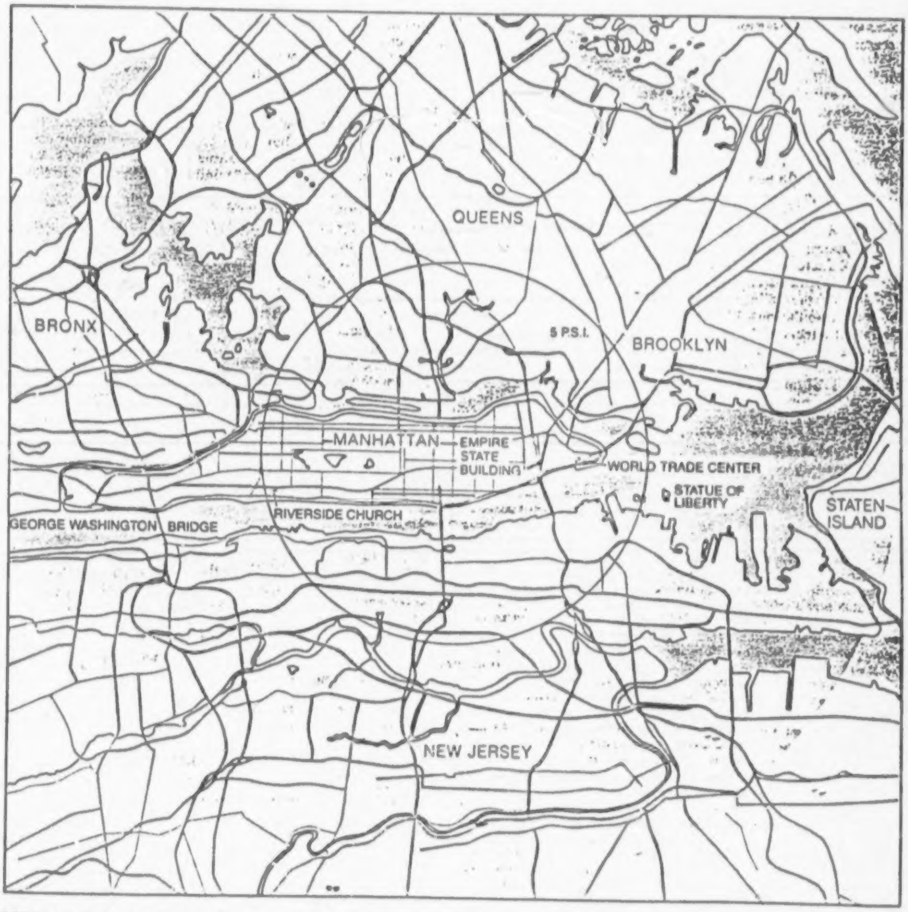
Since retaliatory forces are planned on the basis of assured damage, the consequences of an attack are typically calculated only on the basis of the more predictable blast effects. Consider the problem of allocating a suitable "package" of nuclear weapons to an urban area after a review of the targets within that city. Aim points for each weapon are selected in such a way as to ensure that the desired blast effects will cover all the targets. If the targets are close enough together, a single warhead may suffice. If the targets are dispersed or hardened, it may be preferable to allocate more than one weapon to a target area, as opposed to increasing the yield of a single weapon. This approach guards against the failure of a single large warhead, which would leave a tar-

THE PROMPT EFFECTS of the explosion of a one-megaton nuclear warhead detonated at a height of 6,500 feet over the heart of New York are depicted chronologically in the sequence of scenes on the opposite page. Immediately after such a detonation an extremely hot, luminous fireball would form. The fireball would emit intense thermal radiation (*color*), capable of causing skin burns and starting fires at a considerable distance. The explosion would also give rise to a destructive blast wave, which would move away from the fireball at supersonic speed; at 1.8 seconds after the detonation, for example, the front of the blast wave (*black circle*) would be roughly half a mile ahead of the fireball. In addition the nuclear processes responsible for the explosion would be accompanied by the emission of hard radiation, mainly gamma rays and neutrons (*wavy white lines*), which would have enough range in air to reach the ground in the midtown area. When the primary blast wave from the explosion hit the ground, another shock wave would be caused by reflection. At a certain distance from ground zero (depending on the height of the explosion and the energy yield of the weapon) the primary and reflected wave fronts would fuse near the ground to form a single reinforced Mach front; in the case of a one-megaton warhead detonated at 6,500 feet the Mach effect would begin some 4.6 seconds after detonation at a distance of 1.3 miles from ground zero. At that point the overpressure (that is, the air pressure above ambient atmospheric pressure) would be 16 pounds per square inch (p.s.i.). At 11 seconds after detonation the Mach front would have moved outward to 3.2 miles from ground zero, the overpressure at the Mach front would be 6 p.s.i. and the velocity of the wind just behind the front would be approximately 180 miles per hour; appreciable amounts of thermal radiation and nuclear radiation would continue to reach the ground. At 37 seconds after detonation the Mach front would be nearly 9.5 miles from ground zero, the overpressure at the front would be 1 p.s.i. and the wind velocity behind the front would be 40 miles per hour. (Glass would be broken at overpressures down to .5 p.s.i.) Although thermal radiation would no longer be significant, gamma rays would still reach the ground in potentially lethal amounts. The fireball would no longer be luminous, but it would still be very hot, and it would therefore rise rapidly, causing air to be drawn inward and upward, producing strong air currents called afterwinds. These winds would raise dirt and debris from the city to form the stem of what would eventually become the characteristic mushroom cloud. By 110 seconds after detonation the hot residue of the fireball, while continuing to rise, would have begun to expand and cool. As a result the vaporized fission products and other weapon residues would condense to form a cloud of radioactive particles. By this time the cloud would have risen to a height of seven miles. The maximum height attained by the cloud (after 10 minutes) would be about 14 miles. Ultimately the particles in the cloud would be dispersed by the wind, and unless there were precipitation there would probably be no early (or local) fallout of radioactive material.

get "uncovered." It also reflects the fact that few industrial and military complexes are sufficiently concentrated or have the right shape to be attacked by a single weapon of the type that currently constitutes the bulk of the U.S. strategic arsenal.

Each city has a unique set of target characteristics, but some simple rules make it possible to predict damage and fatalities. In general any structure not specifically designed for blast resistance would be destroyed if it were exposed to an overpressure of five or more pounds per square inch (p.s.i.) above the ambient atmospheric pressure of some 15 p.s.i., and those structures that would not actually collapse would typically be damaged beyond repair. Some reinforced buildings (and heavy equipment inside them) could withstand an overpressure of 40 p.s.i. or more, but if these targets were considered important, an attacker could lower the height at which his weapons were set to explode or could aim his weapons (or allocate new warheads) to achieve the desired effects. Still, as a rule of thumb an overpressure of 5 p.s.i. is considered sufficient to destroy most structures.

The human body can endure a far more intense blast than most buildings. Therefore in a nuclear attack most of



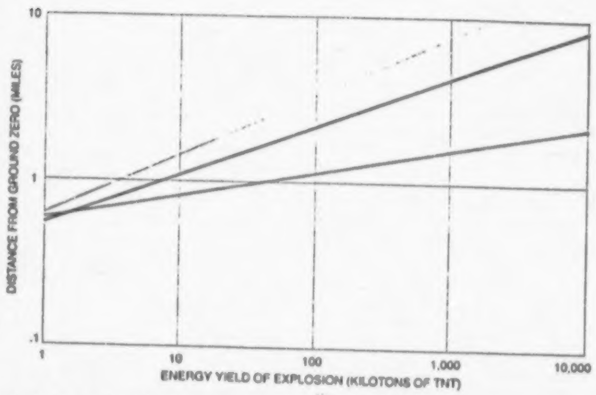
LETHAL AREA is defined by U.S. nuclear-war planners as the circular region within which the number of survivors of a nuclear explosion equals the number of fatalities outside the region. This simplifying assumption makes it possible to arrive at an estimate of the prompt fatalities resulting from a nuclear explosion by multiplying the lethal area by the population density (assuming that the population density over the entire area is uniform). As a general rule the lethal area is considered to extend roughly to the 5-p.s.i. overpressure contour, which for the one-megaton airburst represented on page 36 corresponds to a circular area with a radius of 4.3 miles (*area within black circle*). The lethal-area concept excludes several important (if less predictable) delayed effects of nuclear explosions, such as fires and radioactive fallout. On a clear day, for example, a one-megaton airburst could ignite fires as much as 10 miles away. If these fires were to consolidate into a mass fire, the entire region within that range (*colored area*) would be devastated, enlarging the lethal area fivefold.

the blast casualties would be caused by indirect effects. The bulk of the population would be at risk from being inside or near collapsing buildings, from being hit by debris thrown by the shock wave or from being hurled into an immobile surface. Thermal effects would also cause many fatalities within a certain range, regardless of external conditions. In estimating fatalities the simplifying concept of the "lethal area" is often used. Based on theoretical and empirical data developed by the Atomic Energy Commission in the 1950's, the lethal area is defined as the circular region within which the number of survivors would equal the number of fatalities outside the circle, assuming that the population density over the entire area is uniform.

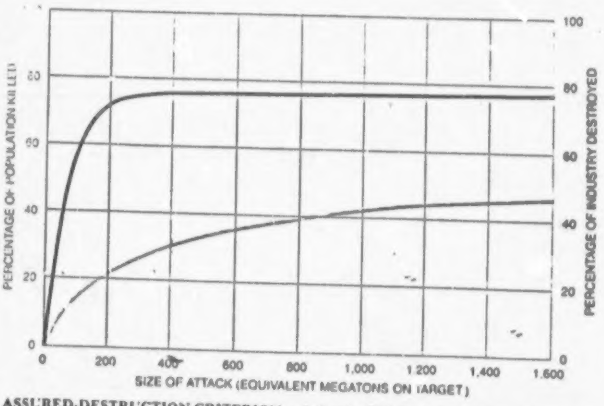
To simplify the calculations the estimated fatalities are redistributed, so that planners consider everyone within the circle to be a fatality and no one outside the circle to be a fatality. An estimate of prompt fatalities is then made by multiplying the lethal area by the population density. The experience of Hiroshima and Nagasaki and also test data indicate that for weapons in the range of 20 kilotons the lethal area extends roughly to the contour within which there is an overpressure of 5 p.s.i. Hence coverage by that overpressure is considered a satisfactory standard for calculating both the fatalities and the economic destructiveness of nuclear explosions.

Nuclear weapons will generate an overpressure of 5 p.s.i. to a distance proportional to the cube root of their yield. For this reason larger weapons are said to distribute their destructive power less efficiently than smaller ones. For example, a 100-kiloton bomb will generate an overpressure of 5 p.s.i. to a range of about two miles. Yet a warhead with 10 times the explosive yield (one megaton) will generate the same overpressure to only about twice that distance. In recognition of the inherently greater efficiency of smaller weapons, a scaled measure known as equivalent megatonnage, defined as the yield of a bomb in megatons raised to the two-thirds power, is considered a better index of countercity capability than the unadjusted yield in megatons. It was calculated by McNamara's systems-analysis staff in the 1960's that the reliable delivery of 400 equivalent megatons would kill 30 percent of the population of the U.S.S.R. and destroy 75 percent of the industrial capacity; more recently the population damage and industrial damage have been estimated to be closer to 35 and 70 percent.

In actuality these damage levels are the lowest that would result from nuclear explosions, since they are typically calculated on the basis of the predictable "prompt" effects described above. When delayed effects (fires, fallout and



TYPICAL RANGES to which three different harmful effects of nuclear weapons extend are represented here for a typical airburst as a function of the energy yield of the explosion. The colored line shows the distance to which thermal radiation can cause second-degree skin burns and ignite fires, creating the risk of a mass fire. The black line measures the radius of the 5-p.s.i. overpressure circle, within which the passage of the blast wave front, followed by 160-mile-per-hour winds, would cause massive urban destruction and a high percentage of fatalities. The gray line gives the range to which prompt nuclear radiation from the explosion would result in 100 percent fatalities. It is evident that under favorable weather conditions the destructive thermal effects of such an explosion could reach well beyond the area of major blast destruction. Prompt nuclear radiation, on the other hand, is clearly not an important damage mechanism for strategic nuclear weapons (which have explosive yields of anywhere from a few tens of kilotons to many megatons), since the areas covered by deadly radiation would also be exposed to severe blast and thermal effects. It is only at much lower yields (on the order of a kiloton or less) that prompt nuclear radiation becomes an important lethal mechanism; that relation in fact is the basic principle of the enhanced-radiation weapon, or neutron bomb.



ASSURED-DESTRUCTION CRITERION, relied on by U.S. strategic planners to determine the retaliatory potential needed by U.S. nuclear forces to deter a surprise attack by the U.S.S.R., is calibrated here in terms of the number of delivered equivalent megatons it would take to destroy key population centers and industrial targets in the U.S.S.R. (Equivalent megatons are defined as the explosive yield of a nuclear weapon raised to the 2/3 power.) Given the decreasing value of adding extra equivalent megatons to such a retaliatory attack, it is evident from these curves that the delivery on target of some 400 equivalent megatons would be more than adequate to achieve assured destruction. Population damage (*color curve*) was estimated in terms of fatalities only; industrial damage (*black curve*) was determined by calculating the "manufacturing value added" destroyed during a U.S. retaliatory attack on the U.S.S.R. (Manufacturing value added is the incremental value imparted to raw materials in any industrial process.)

so on) are introduced, the damage estimates become much higher. The delayed effects also ensure that even if the blast-damage levels cited in assured-destruction definitions were not reached, an all-out nuclear war would still result in the devastation of the combatant countries.

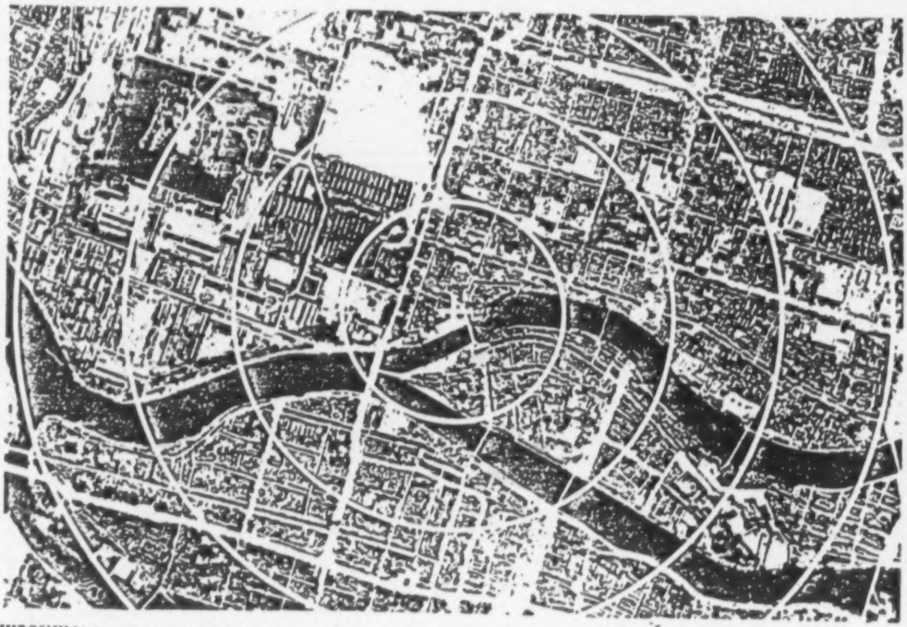
Prompt and delayed nuclear-weapons effects can be contrasted by considering an attack on a typical urban target, for example the greater Boston metropolitan area. The detonation of 10 one-megaton warheads, aimed at local economic and military targets, would generate an overpressure of 5 p.s.i. over more than 500 square miles. More than 1.3 million people would be killed by the prompt blast and thermal effects of the explosions, and more than 80 percent of the area's industrial capacity would be destroyed. It is likely that the secondary effects of the explosions, particularly fires and fallout, would increase these totals.

If conditions were favorable to the attack, the most devastating effect might be incendiary. Under certain weather conditions each one-megaton burst could ignite fires as much as 10 miles away. In such an attack a fire threat would presumably exist throughout much of eastern Massachusetts. Flash-induced fires would be joined by blast-triggered fires from toppled furnaces, stoves and boilers. Scattered debris and ruptured tanks and pipelines would add fuel to the fires. Firebreaks would be bridged by materials hurled by the blast. After the attack the suppression of possibly hundreds of small fires per acre would be a monumental task; water mains would be shattered and firefighting equipment and crews would be destroyed or disabled. In Hiroshima some 70 percent of the city's firefighting equipment was crushed in the collapse of firehouses and 80 percent of the firemen did not report to their posts.

Depending on weather conditions and the characteristics of the target area (particularly the density of flammable structures), the many individual fires might consolidate into one of two types of mass fire: a firestorm or a conflagration. A firestorm is driven by a strong vertical updraft of heated air, which is replaced by cool air sucked in from the periphery of the fire. A conflagration is driven in addition by a strong ground wind that was present before the attack. Whereas a firestorm continues only as long as its centripetal winds do, a conflagration can continue as long as fuel is available.

The consequence of a mass fire is total devastation within the affected area. The temperatures in a mass fire can exceed 1,000 degrees Celsius, a temperature higher than that necessary to melt glass and metal and to burn ordinarily fireproof materials. In Hiroshima an atomic bomb with a yield on the order of 15 kilotons caused a firestorm that lasted for six hours, totally destroying 4.4 square miles of the city. American cities are constructed of materials that are more fire-resistant than those in Hiroshima; on the other hand, American cities are more built up and more fuels, notably gasoline and heating oil, are available to feed fires. Most important, the yields of many modern strategic nuclear weapons exceed those exploded at Hiroshima and Nagasaki by two or more orders of magnitude. In addition much of the area under attack would be exposed to thermal radiation from more than one fireball.

Blast shelters would provide little protection against large fires. The survival of the occupants of such a shelter would depend critically on the temperature and humidity inside the shelter, and if mass fires were to start, the problem of maintaining a shelter environment in which people could survive would be aggravated beyond solution. Moreover, unless there was an independent supply of oxygen for each shelter, carbon monoxide and other toxic gases generated by



HIROSHIMA is seen from directly above in these U.S. Air Force reconnaissance photographs made before (*left*) and after (*right*) the atomic bombing of that city on August 6, 1945. The cross marks ground zero, the point on the ground directly under the explosion. The

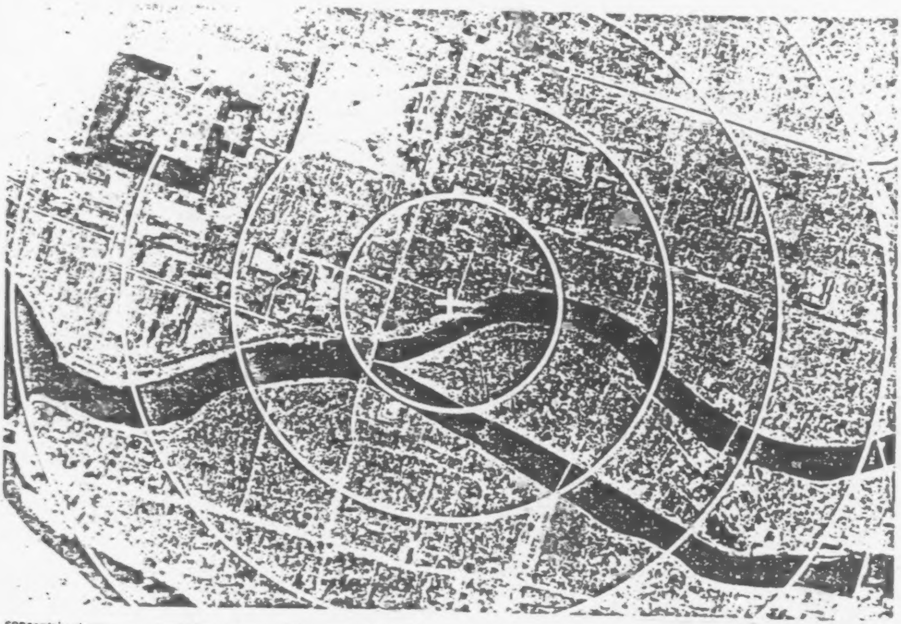
the fire could be deadly to the occupants. The heating of shelters, both by flames and by heated rubble (which could remain intolerably hot for days after the end of a fire), would jeopardize the occupants of shelters with an isolated atmosphere. In Dresden, where a firestorm ignited by chemical bombs killed more than 100,000 people in 1945, only those inhabitants who had left their shelters before the firestorm began were able to survive the twin threats of noxious gases and shelter heating.

After a nuclear attack many people would be disabled, trapped in wrecked buildings or prevented from fleeing the city because the streets were blocked by debris or fire. If mass fires were to form, which seems to be the probable result of multiple megaton bursts, the survivors among those who had escaped prompt incapacitation might be few. If mass fires were to begin in the Boston area, for example, the number of fatalities could be increased by 500,000.

Another factor not included in many assured-destruction calculations is radioactive fallout. Fallout results from the condensation of the radioactive byproducts of a nuclear explosion on materials fused by the intense heat of the fireball and (to a much smaller extent) from the conversion of nonradioactive materials into radioactive ones by the absorption of neutrons from the nuclear reactions of the explosion. If a nuclear weapon were to be exploded at or near the earth's surface, fallout would be an acute threat. Large amounts of debris would be scooped up into the rising cloud, later to fall out (or more likely be washed out) of the cloud in lethal amounts for hundreds of miles downwind. A dose of ionizing radiation measuring between 400 and 500 rems (an index of the biological effects of different types of radiation on man) delivered over a period of several days would kill half of the people who had been exposed. A dose of between 200 and 300 rems would kill somewhat fewer than 20 percent (assuming prompt medical treatment), but severe radiation-related blood symptoms, including diminished immunological response, could add extra fatalities by contributing to lethal infections. If 10 one-megaton weapons were exploded at ground level (to maximize fallout rather than blast and thermal effects), as many as a million New England residents who were not exposed to the immediate blast and thermal effects of the nuclear explosions would be subjected to dangerous levels of radiation. Even with optimistic assumptions about the availability of shelter and provisions, the fallout fatalities that would be added to the Boston-area toll could be as many as 500,000. An attack of this type might well mix airbursts and ground bursts to create maximum levels of both kinds of damage.

The number of fatalities from fire and radiation would grow steadily after such an attack, in part because medical facilities and personnel would be destroyed. Burn victims would present an exceptional medical problem, since serious burn cases require intensive and immediate treatment if they are to survive. The ability of any medical system to handle large numbers of such casualties is limited even in peacetime. The influx of some 50 survivors of the collision of two jet airliners on Tenerife in the Canary Islands a few years ago put a strain on burn centers in the U.S., which have a maximum capacity of about 130 patients. After a nuclear attack, of course, the number of burn cases would be orders of magnitude greater, and access to medical treatment would be far more difficult.

Existing medical services would be further burdened by the incidence of injuries well beyond areas of widespread mortality. The danger of injury from projected missiles (mainly shards of glass from shattered windows) would exist more than eight miles out from the

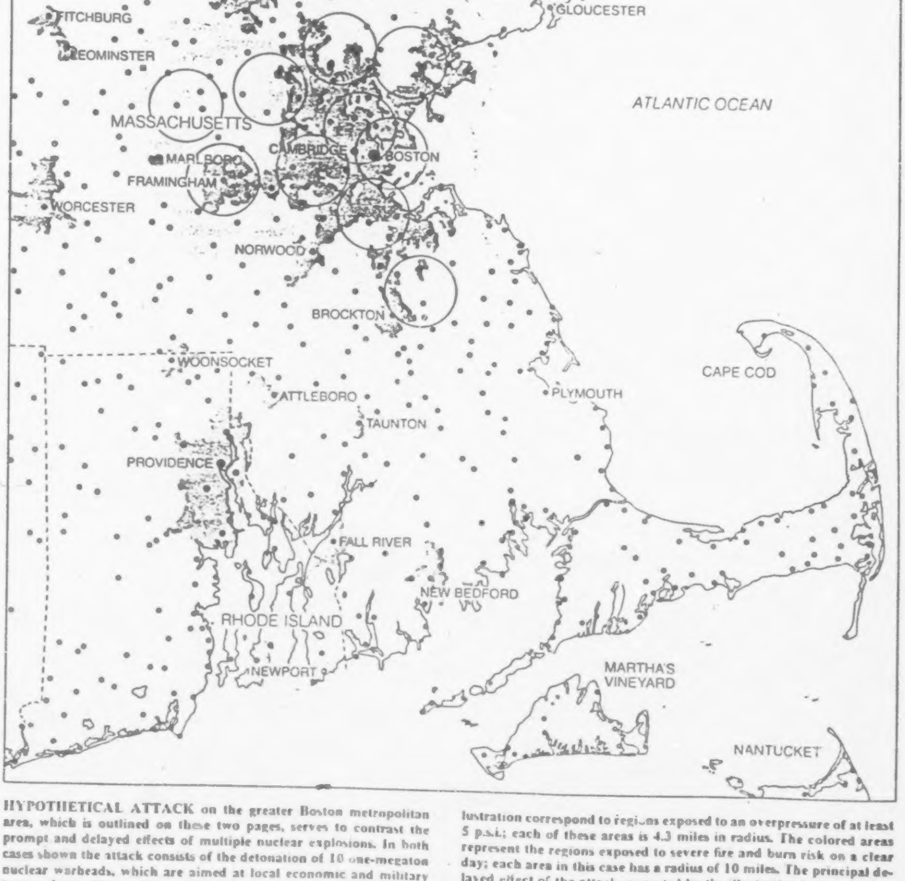


concentric circles are at 1,000-foot intervals. The firestorm following the prompt effects of the explosion lasted for about six hours and totally destroyed 4.4 square miles of the city. The explosive yield of the weapon that caused this devastation was on the order of 15 kilotons.

center of a one-megaton blast, and severe burns could be common out to nine miles, depending on weather conditions. Many victims of burns, radiation sickness and other mortal injuries who did not die immediately would require intensive (but under the circumstances unavailable) medical care. The management of less severely injured people and the very young, the very old and those with special medical needs would be complicated by the scarcity of food, shelter and medicine.

The survivors of an all-out nuclear attack would include many who would be permanently incapacitated by crippling injuries, blindness and other causes. Any medical effort would be further degraded by the destruction of public-health facilities and personnel, the proliferation of disease-causing organisms (which tend to survive high radiation levels) and other difficulties, such as the seemingly insoluble problem of disposing of the dead. The total regional casualties following an attack on the Boston area with both airburst and groundburst nuclear weapons could well exceed two million dead, with roughly the same number wounded or sick.

The assured-destruction concept also ignores certain strategic issues. It is typically argued that the U.S.S.R. is pursuing two types of program that would enable it to blunt the effectiveness of a U.S. retaliatory attack. The first program seeks to reduce the number of U.S. warheads arriving at their targets by de-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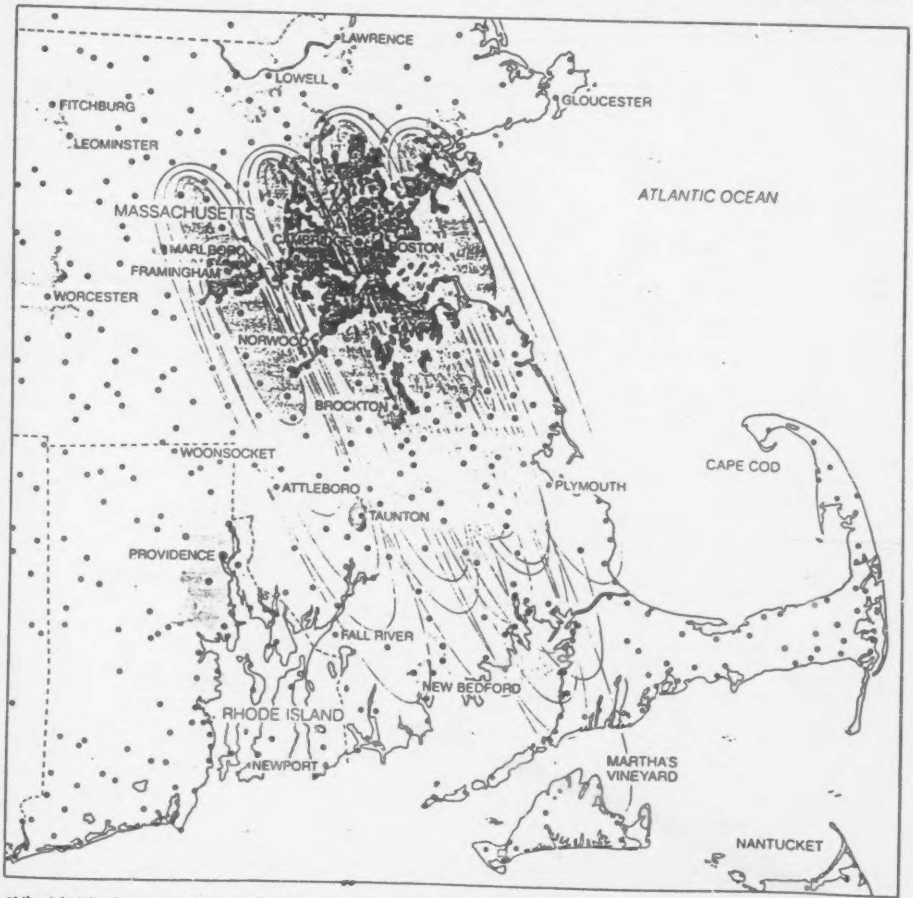
TAUNTON
PROVIDENCE
FALL RIVER
NEW BEDFORD
RHODE ISLAND
NEWPORT
MARTHA'S VINEYARD
NANTUCKET

HYPOTHETICAL ATTACK on the greater Boston metropolitan area, which is outlined on these two pages, serves to contrast the prompt and delayed effects of multiple nuclear explosions. In both cases shown the attack consists of the detonation of 10 one-megaton nuclear warheads, which are aimed at local economic and military targets. In the illustration at the left it has been assumed that all the weapons have been detonated at an altitude that has been selected to maximize blast and thermal effects. Black circular outlines in the illustration correspond to regions exposed to an overpressure of at least 5 p.s.i.; each of these areas is 4.3 miles in radius. The colored areas represent the regions exposed to severe fire and burn risk on a clear day; each area in this case has a radius of 10 miles. The principal delayed effect of the attack suggested by the illustration is the risk of a regionwide firestorm or conflagration, which could add 500,000 fatalities to the assured-destruction estimate of 1.3 million killed by the prompt blast and thermal effects of the explosions. In the illustration stroying U.S. strategic forces in a surprise attack and by intercepting as many surviving warheads as possible before they reach their targets in the U.S.S.R. The second program seeks to minimize the damage done by arriving U.S. weapons by evacuating urban residents and by dispersing and hardening industrial sites. Because the Russians could thereby "deny" important urban and economic targets to U.S. attack it is maintained that U.S. forces would fail to satisfy the assured-destruction damage levels, and that the U.S.S.R. would retain the industrial base, personnel and administration necessary for a rapid postwar recovery.

In spite of the alleged success of the U.S.S.R. in these endeavors, neither strategy could effectively reduce the devastation of an all-out nuclear war. Furthermore, neither effort would appreciably enhance the potential of the U.S.S.R. for recovery. On the contrary, such schemes only appear to reduce U.S. retaliatory capabilities in the perspective of the narrow and arbitrary definition of assured destruction discussed above.

Such analyses ignore the fact that even under the worst circumstances the U.S. would be able to mount a more than adequate retaliatory attack. Any Russian plan to degrade the U.S. assured-destruction capability would face the formidable task of reducing U.S. forces substantially below the level of 400 deliverable equivalent megatons. (Actually the task might be even more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at the right it has been assumed that all 10 of the warheads have been detonated at ground level in order to maximize the effects of radioactive fallout. (Typical January wind patterns have been assumed in drawing the contours.) The dark-colored areas are those that are covered by an amount of radiation that would be fatal to at least 80 percent of the exposed population. The medium-colored areas are those in which at least 50 percent of the exposed population would die of radiation sickness. The light-colored areas are the probable extent of the region in which clinical radiation symptoms would be evident in much of the exposed population, resulting in perhaps 20 percent fatalities. (Presumably the survivors would also be subjected to the effects of additional long-term radioactive fallout from attacks on neighboring regions.) The total number of casualties in the Boston region following an attack that made use of a suitable combination of airburst and ground-burst nuclear weapons could well exceed two million dead, with approximately the same number wounded or sick.

difficult, because a well-planned American attack of even 200 equivalent megatons could still promptly kill a fifth of the U.S.S.R.'s population and destroy more than two-thirds of its industry, thereby satisfying the requirements of assured destruction.)

It is extremely unlikely that a preemptive Russian first strike could achieve this goal. For one thing, 400 equivalent megatons is only a fraction of the current U.S. nuclear arsenal. More than half of the current U.S. arsenal of more than 6,000 equivalent megatons is carried by missile-launching submarines on station, by bombers on alert at Strategic Air Command bases and by silo-based missiles, all of which are capable of going into action within a few minutes of a Presidential order. The rest of the U.S. strategic forces consist mainly of bombers not on alert and submarines in port for maintenance. If a Russian surprise attack were to destroy many land-based U.S. missiles in their silos and all the nonalert bombers and submarines, more than 2,000 equivalent megatons would remain available for retaliatory action. Even if an unexpectedly large number of U.S. weapons were to malfunction or to be destroyed in flight, more than 1,500 equivalent megatons could still be delivered with high confidence. These figures assume "worst case" conditions from a U.S. perspective: if some warning were available prior to such a Russian attack, extra bombers and submarines could be alerted and the number of deliverable equivalent megatons would more than double.

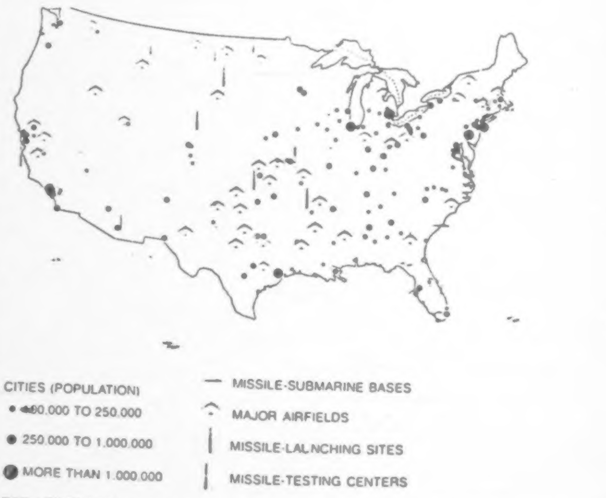
Because of the availability of what are sometimes described as "overkill" forces any effort to reduce the numbers or effectiveness of the arriving U.S. warheads is bound to fail. For example, Moscow is protected by an anti-ballistic-missile (ABM) system that is limited by treaty to 100 missile launchers. (Currently only 64 missiles are deployed in that system.) In the event of a missile attack those missiles could destroy a certain fraction of the incoming missiles. U.S. planners could easily compensate for this potential attrition by several strategies, one of which would be to allocate extra warheads to the "Moscow package" based on generous theoretical assumptions about the effectiveness of the Moscow ABM system.

The assured-destruction criterion implicitly assumes what may be the least probable scenario for a general nuclear war. It is extremely unlikely that an all-out war would begin with a massive surprise attack by either side on the other side's cities. Such a war would more probably follow an escalating crisis that might begin with limited nuclear strikes on military targets. These alternative scenarios imply that city populations would have ample warning of a possible or probable nuclear attack, with the result that evacuation and other tactics for reducing damage could be pursued. If this were to be the situation, the character of the city population would clearly have changed by the time of an attack. Since assured destruction is calculated according to peacetime population densities and the calculations rely on certain assumptions about the disposition of city dwellers and workers on a day-to-day basis, the programmed fatality levels may not be reached under realistic circumstances.

The assured-destruction criterion also assumes that a general nuclear war would consist of a single massive "countervalue" strike: a strike against both military and economic targets. Countervalue strikes might well, however, remain at a relatively low level of intensity for some time. A limited countervalue exchange might consist of attacks on industrial locations away from large cities in order to discourage escalation to attacks with the largest possible number of fatalities. (The Russians in particular have built some key installations in remote areas, where they could be attacked with a relatively low level of fatalities.) Strikes against cities might be preceded by a warning or an ultimatum, which would clearly encourage evacuation. A general war might even begin with a slow campaign of "city-trading." In other words, virtually any change in assumptions radically alters the context of the assured-destruction scenario and casts doubt on the accuracy of fatality estimates.

In fact, except in the circumstances of certain specialized scenarios, there will always be an opportunity for a country to evacuate its urban centers to some extent, regardless of the degree to which the country has prepared for such evacuation. (For example, on September 1, 2 and 3, 1939, the British government evacuated some 1.5 million women and children from Britain's major cities, and in the same three days an additional two million people moved out on their own initiative.) The wide availability of private-automobile transport in the U.S. probably more than compensates for any current Russian evacuation plans and training.

Nevertheless, allegations of evacuation planning in the U.S.S.R. have inspired much concern in the U.S. According to a recent report of the Central Intelligence Agency, if the Russians were to have at least one week to thoroughly evacuate their cities and shelter refugees against radioactive fallout, war-related casualties could be reduced to the "low tens of millions, about half of which would be fatalities." Some analysts have gone so far as to term these fatality levels "acceptable" in view of the fact that the U.S.S.R. suffered 20 million dead in World War II. Even if evacuation could reduce the number of prompt fatalities, however, the degree of damage the U.S. could inflict on the unprotectable economic resources of the U.S.S.R. would be so great that the U.S.S.R. would be eliminated as a major industrial power.



RELATIVE CONCENTRATIONS of potential population targets and military targets in the U.S. and the U.S.S.R. are suggested by these two maps. The black dots indicate the location of the largest cities in each country. The colored symbols designate strategic-weapons instal-

One purpose of any campaign of strategic bombardment is to reduce an enemy's potential for supporting armed forces in the field. In World War II factories, transportation systems and power plants were attacked. One goal of such bombing campaigns was to destroy industries on which other economic sectors relied, depriving those sectors of essential inputs and leading to an expanding industrial incapacitation. The bombing of Germany failed to have this effect, in part because of limitations on the size of chemical-explosive payloads. Attacks on a given target system had to be spread out over many raids, and so the surviving facilities could be "jury-rigged" to compensate for the damage done to certain parts of the industrial network. Civilians left homeless in attacks could be housed in nearby towns that had not been damaged. Even after the atomic bombing of Hiroshima and Nagasaki enough aid was available in surrounding communities to significantly aid the survivors.

The deployment of large numbers of nuclear weapons has radically changed the context of strategic bombing. The forces currently deployed by the U.S. and the U.S.S.R. are able to destroy the entire industrial structure of any nation. Moreover, this damage can be done all at once, so that little assistance would be available for those targets that had come under attack.

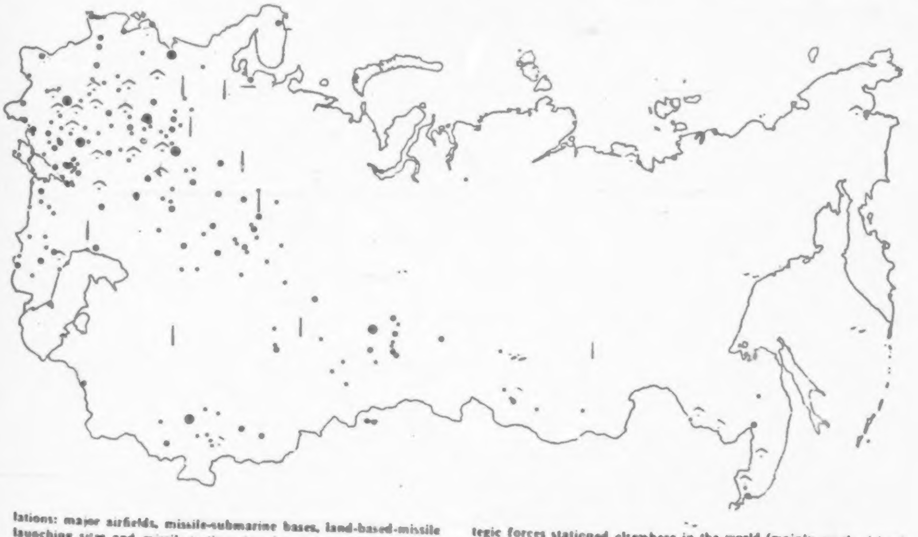
In both the U.S. and the U.S.S.R. a limited number of facilities comprise the bulk of the productive capacity in many major industries. The centrally planned economy of the U.S.S.R. in particular has many vulnerable bottlenecks and choke points. Hence the destruction of a single target or very few targets could disrupt production in many other industries. Because of this concentration 100 equivalent megatons, corresponding to the payload of the missiles carried by five or six Poseidon submarines, would be sufficient to destroy crucial industries without which the Russian economy could not sustain itself.

For example, a study conducted recently by the Office of Technology Assessment of Congress showed that a U.S. attack on petroleum refineries in the U.S.S.R. could, with only some 40 low-yield nuclear warheads, destroy about three-fourths of the U.S.S.R.'s entire refining capacity. Comparatively few warheads could also destroy the transportation, energy, maintenance and management resources needed for any postwar economic recovery. The Russian energy system is particularly vulnerable to attack and is crucial for recovery. For instance, nearly all the intercity freight in the U.S.S.R. is shipped over electrified rail networks, whereas much of it in the U.S. goes by truck.

These kinds of figures should not be taken as evidence that the U.S. economy is somehow less vulnerable than that of the U.S.S.R. The Russians have more than enough warheads to cover similar U.S. targets. Rather, it is instructive to remember, as the CIA report noted, that "the coordination of requirements with available supplies and transportation is a complex problem for Soviet planners even in peacetime, let alone following a large-scale nuclear attack on the U.S.S.R."

Even if the Russian evacuation plans were successful, they would only defer, not prevent, the impact of the war on civilians. A nation's fixed medical, technical and educational base would, after all, be destroyed in a nuclear war. Recovery stockpiles and facilities could also be targeted. If some food, pharmaceuticals, clothing, equipment and spare parts did survive, there would be neither the administrative structure to allocate the goods nor the transport to ship them where they were needed. The destruction of refineries and electric-power stations could interdict resupply, and shortages could develop quickly. Perishable goods, including many foods and drugs, would be lost if electric power were cut off. The devastation of housing would make summer life difficult and winter existence intolerable. This would be particularly true in the U.S.S.R., where outside cities there are few alternative forms of shelter such as hotels. In short, civil defense might protect some people, but it could not prevent the widespread destruction of property essential to the support of life. The economic interdependence of an industrialized nation is a vulnerability that cannot be defended.

A nation's administrative and social structure would also be disrupted by nu-



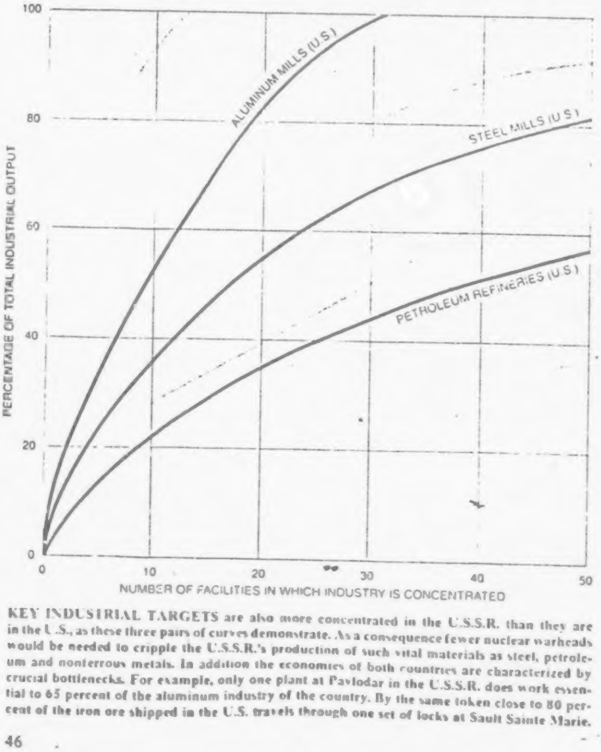
lations: major airfields, missile-submarine bases, land-based-missile launching sites and missile-testing sites (*see key at bottom left*). In addition to the installations shown here the U.S. has a variety of strategic forces stationed elsewhere in the world (mainly on the island of Guam and in Alaska). In general suitable targets for nuclear attack are more concentrated in the U.S.S.R. than they are in the U.S.

clear attack to the point that a political system might be shattered beyond reconstitution. Although special bunkers are being constructed to protect the bureaucratic and internal-security apparatus of the Soviet government in the event of war, the U.S. does not lack the means to attack those shelters.

The delayed effects of a nuclear war between the U.S. and the U.S.S.R. would propagate far beyond the borders of the antagonists and their allies. Worldwide effects would result mainly from the fact that the stem and cloud of most nuclear explosions would penetrate the stratosphere and deposit several kinds of radioactive material in it. Unlike the lower part of the atmosphere, the stratosphere lacks the moisture and shear motions needed to quickly sort out particulate and gaseous matter. Since such materials would remain in the stratosphere for a long time, their effects would be diluted. One consequence of this long residence time, however, would be wide dispersion. Thus although stratospheric effects would be less intense than lower-atmospheric ones, they would last longer and be more widespread.

A report issued by the National Academy of Sciences in 1975 listed three effects of nuclear war that might have adverse worldwide impacts. First, stratospheric ozone might be depleted, because nitrogen oxides made from atmospheric nitrogen and oxygen by the heat of nuclear explosions would be injected into the stratosphere, where they would aid in the conversion of ozone into molecular oxygen. Second, the deposition of large amounts of dust in the upper atmosphere could alter the amount of solar radiation arriving at the earth's surface. Third, hazardous radioactive isotopes could be dispersed through the stratosphere, falling out slowly on a worldwide scale.

Stratospheric ozone plays an important role in life on the earth by screening out harmful ultraviolet radiation. The NAS report estimated that a 10,000-megaton nuclear war could destroy half of the ozone in the Northern Hemisphere and about 30 percent of the ozone in the Southern Hemisphere. As opponents of the supersonic transport aircraft and fluorocarbon spray-can propellants have contended, the depletion of the ozone layer could lead to a variety of medical and environmental problems. Higher cancer rates and harmful effects on plants, including crop plants, could result. The destruction of stratospheric ozone on this scale could upset the thermal structure of the upper atmosphere and lead to worldwide temperature changes. After such a war ozone levels might not return to normal levels for many years.



KEY INDUSTRIAL TARGETS are also more concentrated in the U.S.S.R. than they are in the U.S., as these three pairs of curves demonstrate. As a consequence fewer nuclear warheads would be needed to cripple the U.S.S.R.'s production of such vital materials as steel, petroleum and nonferrous metals. In addition the economies of both countries are characterized by crucial bottlenecks. For example, only one plant at Pavlodar in the U.S.S.R. does work essential to 65 percent of the aluminum industry of the country. By the same token close to 80 percent of the iron ore shipped in the U.S. travels through one set of locks at Sault Sainte Marie.

A single one-megaton surface burst would also project thousands of tons of fine dust into the stratosphere. The dust could absorb, reflect and scatter radiation arriving from the sun or reflected from the earth, and there have been suggestions that this effect could lead to a change in the weather at the earth's surface. According to the NAS study, however, a 10,000-megaton war would inject no more dust into the stratosphere than was thrown up by the explosion of the volcano Krakatoa in 1883. By extrapolating from such volcanic events the NAS report concluded that only a slight change in surface weather conditions might result.

Radioactive isotopes would be distributed worldwide by stratospheric transport processes. Since these isotopes would have a relatively long residence time in the stratosphere, many of the dangerous short-lived ones would decay before they could reach the ground. Nevertheless, some hazardous isotopes, such as strontium 90, cesium 137, iodine 131 and carbon 14, would persist and might enter the food chains of the biosphere. The NAS report did not suggest that this fallout would have the kind of worldwide lethal consequences for human life that are depicted in novels such as Nevil Shute's *On the Beach.* Regional concentrations of fallout in the combatant nations (and neighboring nations) could nonetheless present an acute radiation hazard to many evacuees and rural residents who might not have been directly imperiled during an attack on cities. Less intense "hot spots" could appear at greater distances, with adverse biological consequences. Few parts of the attacked country would escape the threat of fallout, since a thorough attack would cover economic and military targets nationwide, leaving most areas contaminated.

Atmospheric phenomena are complex, and it is not clear how a 10,000-megaton nuclear war might influence climate. Although the NAS study estimated that the effects of ozone depletion and dust loading probably would not have an irreversible impact on global weather patterns, the report did indicate that changes of a much more serious nature could not be excluded. The possibility of synergistic actions among these various effects cannot be ignored. For example, it has been noted that a global cooling of only one degree C. could eliminate all wheat growing in Canada.

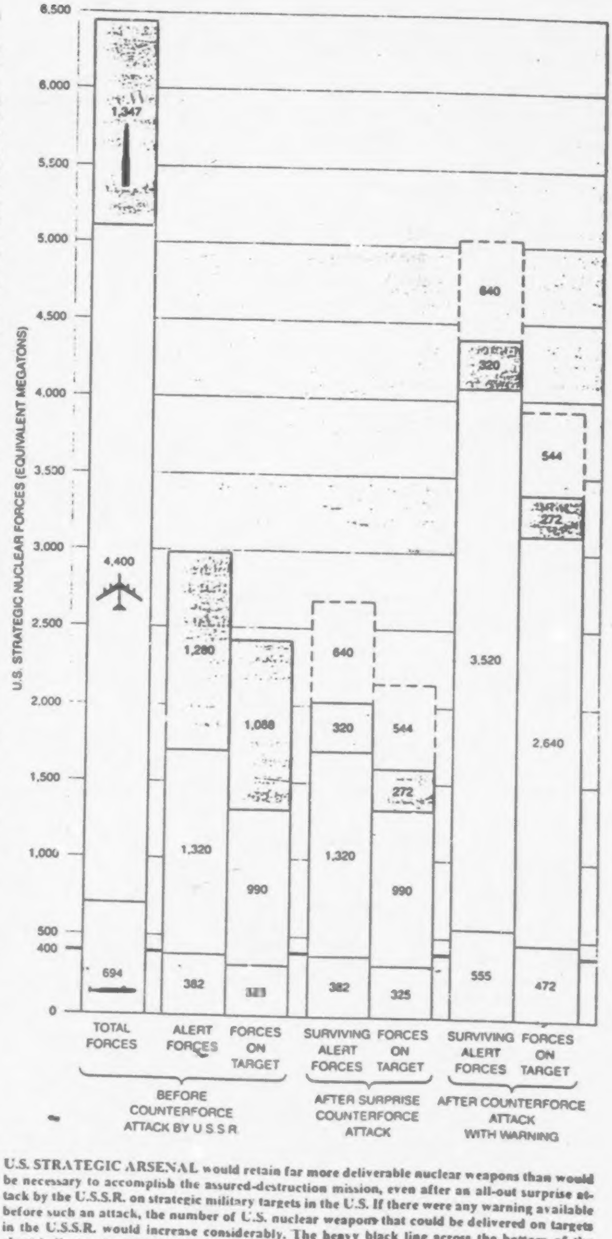
Direr possibilities include the expansion or melting of polar ice.

The NAS report did not examine possible changes in continental weather resulting from effects such as fires. A single 10-megaton airburst could ignite a forest fire covering thousands of square miles. The burning of the broad grasslands and forests of the U.S. and the U.S.S.R. could defoliate the natural ground cover, thereby changing the reflectivity of the earth's surface and giving rise to weather changes. Particulate combustion products thrown into the atmosphere by forest fires would absorb and reflect solar radiation, and they would also act as nucleation centers for the formation of water droplets and ice crystals, thereby increasing the cloud cover and altering the distribution of precipitation. Such local effects could exacerbate the worldwide phenomena cited above.

Finally, just as the various components of a national economy are interlocked, so nations themselves are interdependent. The destruction of the economies of the major powers by a nuclear war would be a massive blow to the economies of nations dependent on those powers for the exchange of commodities and technology. The less developed countries in particular would suffer, since at this stage of their development they need to import technology from more developed countries.

In sum, the cumulative effects of an all-out nuclear war would be so catastrophic that they render any notion of "victory" meaningless. The formal methodologies of the assured-destruction scenarios do not reveal the full extent of these effects. Moreover, arguments that throw doubt on the sufficiency of the deterrent capability of the U.S. exclude some of the most profound and long-lasting of these effects. When the delayed effects of all-out war are taken into consideration, it should become clear that no countermeasure would significantly lessen the degree of devastation that would surely occur. Even if a highly efficient program for the evacuation of cities could substantially reduce prompt fatalities, it could not prevent the delayed social consequences of industrial and economic devastation. The magnitude of either the prompt disaster or the delayed one would be so great that neither disaster could ever be considered tolerable.

There are many steps that could be taken by both sides to diminish the likelihood of an all-out nuclear war. Many of them are now the subject of strong disagreement. One step in the right direction would be to reframe the currently misleading concept of assured destruction in more realistic terms to reflect the full extent of the catastrophe that would be represented by a nuclear war.



U.S. STRATEGIC ARSENAL would retain far more deliverable nuclear weapons than would be necessary to accomplish the assured-destruction mission, even after an all-out surprise attack by the U.S.S.R. on strategic military targets in the U.S. If there were any warning available before such an attack, the number of U.S. nuclear weapons that could be delivered on targets in the U.S.S.R. would increase considerably. The heavy black line across the bottom of the chart indicates the 400 equivalent megatons thought to be sufficient to kill 35 percent of the people in the U.S.S.R. Strategic forces above this level are referred to as overkill capability.

BIBLIOGRAPHY

Readers interested in further explanation of the subjects covered by the articles in this issue may find the following lists of publications helpful.

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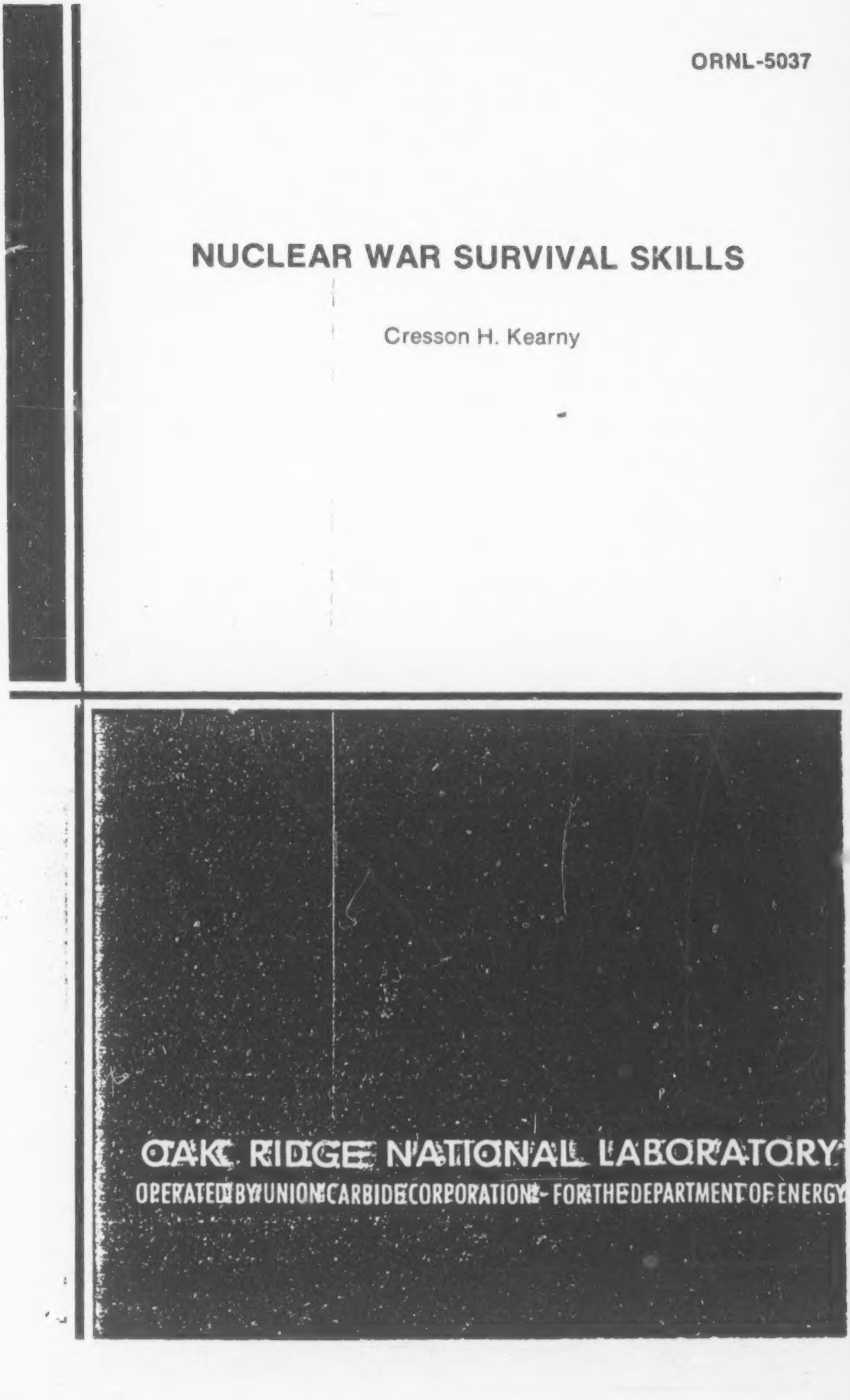
We are also deeply concerned that this report reached the conclusion that there were no meaningful civil defense measures which would provide significant protection to the American public. We realize that protection in the event of a full scale nuclear war will be entirely relative. However, the following article, which is actually Chapter 1 of a longer report entitled "Nuclear War Survival Skills," written by Cresson H. Kearney for the Oak Ridge National Laboratory in 1979, indicates that there are, in fact, significant steps which can be taken to considerably lessen the potential consequences. We note with particular interest the author's assertion in the summary that the Soviet Union is spending forty times as much per capita than is the United States, and that even Switzerland is spending more than twenty times as much on civil defense measures. For those who are interested in the current state of civil defense measures and inventions which could be used by untrained citizens we commend the following information and suggest that the remainder of the publication contains considerable detailed information.



ORNL-5037

NUCLEAR WAR SURVIVAL SKILLS

Cresson H. Kearny

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION • FOR THE DEPARTMENT OF ENERGY

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ENERGY DIVISION
Solar and Special Studies Section

NUCLEAR WAR SURVIVAL SKILLS

Cresson H. Kearny

Date Published—September 1979

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

Summary

The purpose of this book is to provide Americans with information and instructions that will significantly increase their chances of surviving a possible nuclear attack. It brings together field-tested instructions that, if followed by a large fraction of Americans during a crisis that preceded an attack, could save millions of lives. The author is convinced that the vulnerability of our country to nuclear threat or attack must be reduced and that the wide dissemination of the information contained in this book would help achieve that objective of our overall defense strategy.

Underlying the advocacy of Americans' learning these down-to-earth survival skills is the belief that if one prepares for the worst, the worst is less likely to happen. Effective American civil defense preparations would reduce the probability of nuclear blackmail and war. Yet in our world of increasing dangers, it is significant that the United States spends much less per capita on civil defense than many other countries. The United States' annual funding is about 50 cents per capita, whereas Switzerland spends almost $11 and, most importantly, the Soviet Union spends approximately $20.

In the first chapter the myths and facts about the consequences of a massive nuclear attack are discussed. As devastating as such an attack would be, with adequate civil defense preparations and timely warning much of the population could survive.

The information and instructions given in subsequent chapters tell the average citizen how to improve his and his family's chances of surviving a nuclear attack by working together to build expedient shelters and homemade life-support equipment. The reader is urged to make at least some of these low-cost preparations before a crisis arises. The main emphasis, however, is on survival preparations that could be made in the last few days of a worsening crisis.

This book includes chapters on psychological preparations, warning and communications, and evacuation. Because the greatest need would be for shelter that would provide good protection against fallout radiation and also would permit prolonged occupancy, much of the book deals with this subject. These chapters describe the building of expedient shelters, their ventilation and cooling, the purification and storage of adequate water, the processing and cooking of whole grains and legumes, fallout meters, protection against fires and carbon monoxide, and expedient furnishings for shelters. Other chapters cover sanitation and preventive medicine, medical advice for nuclear survivors lacking the help of doctors, improvised footwear and clothing, and advice on minimum preparations that can be made at low cost and should be made before a crisis arises.

One appendix of the handbook gives detailed, field-tested instructions for building six types of earth-covered expedient fallout shelters, with criteria to guide the choice of which shelter to build. The design features of several types of expedient blast shelters are described in another appendix. Two others contain instructions for making an efficient shelter-ventilating pump and a homemade fallout meter that is accurate and dependable. Both of these essentials can be made with inexpensive materials found in most households. Drawings are used extensively, as are photographs of people actually building and living in the various shelters.

This first-of-its-kind report is primarily a compilation and summary of civil defense measures and inventions developed at ORNL over the past 14 years and field-tested in six states, from Florida to Utah. It is the first comprehensive handbook of survival information for use by untrained citizens who want to improve their chances of surviving a possible nuclear attack.

Chapter 1

The Dangers from Nuclear Weapons: Myths and Facts

An all-out nuclear war between Russia and the United States would be the worst catastrophe in history, a tragedy so huge it is difficult to comprehend. Even so, it would be far from the end of human life on earth. The dangers from nuclear weapons have been distorted and exaggerated, for varied reasons. These exaggerations have become demoralizing myths, believed by millions of Americans.

While working with hundreds of Americans building expedient shelters and life-support equipment, I have found that many people at first see no sense in talking about details of survival skills. Those who hold exaggerated beliefs about the dangers from nuclear weapons must first be convinced that nuclear war would not inevitably be the end of them and everything worthwhile. Only after they have begun to question the truth of these myths do they become interested, under normal peacetime conditions, in acquiring nuclear war survival skills. Therefore, before giving detailed instructions for making and using survival equipment, we will examine the most harmful of the myths about nuclear war dangers, along with some of the grim facts.

- **Myth:** Fallout radiation from a nuclear war would poison the air and all parts of the environment. It would kill everyone. (This is the demoralizing message of *On the Beach* and many similar pseudoscientific books and articles.)

- **Facts:** When a nuclear weapon explodes near enough to the ground for its fireball to touch the ground, it forms a crater. (See Fig. 1.1.) Many

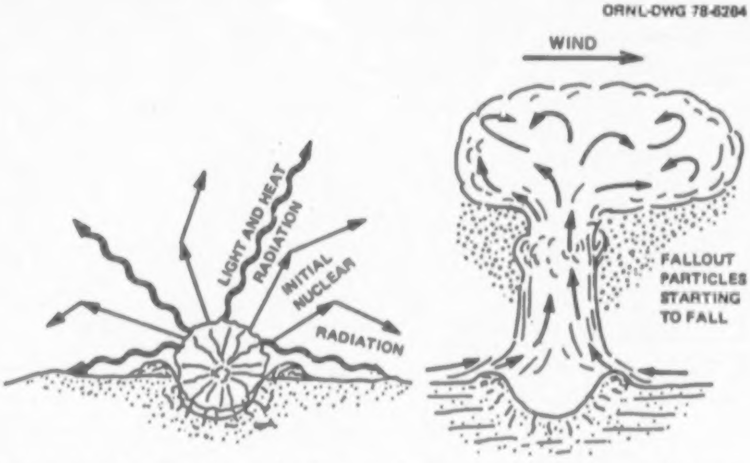


Fig. 1.1. A surface burst. In a surface burst, the fireball touches the ground and blasts a crater.

thousands of tons of earth from the crater of a large explosion are pulverized into trillions of particles. These particles are contaminated by radioactive atoms produced by the nuclear explosion. Thousands of tons of the particles are carried up into a mushroom-shaped cloud, miles above the earth. These radioactive particles then fall out of the mushroom cloud, or out of the dispersing cloud of particles blown by the winds—thus becoming fallout.

Each sand-like, contaminated particle continuously gives off invisible radiation, much like a tiny X-ray machine—while in the mushroom cloud, while descending, and after having fallen to earth. The descending radioactive particles are carried by the winds like the sand and dust particles of a miles-thick sandstorm cloud—except that they usually are blown at lower speeds and in many areas the particles are so far apart that no cloud is seen. The largest, heaviest fallout particles reach the ground first, in locations close to the explosion. Many smaller particles are carried by the winds for tens to hundreds of miles before falling to earth. At any one place where fallout from a single explosion is being deposited on the ground in concentrations high enough to require the use of shelters, deposition will be completed within a few hours.

The smallest fallout particles—those tiny enough to be inhaled into a person's lungs—are invisible to the naked eye. These tiny particles fall so slowly, from heights miles above the earth, that the winds carry them thousands of miles away from the site of the explosion before they reach the ground.

The air in properly designed fallout shelters, even those without air filters, is free of radioactive particles and safe to breathe except in a few rare environments—as will be explained later.

Fortunately for all living things, the danger from fallout radiation lessens with time. The radioactive decay, as this lessening is called, is rapid at first, then gets slower and slower. The dose rate (the amount of radiation received per hour) decreases accordingly. Figure 1.2 illustrates the rapidity of the decay of radiation from fallout during the first two days after the nuclear explosion that produced it. R stands for roentgen, a measurement unit often used to measure exposure to gamma rays and X rays. Fallout meters called dosimeters measure the *dose* received by recording the number of R. Fallout meters called survey meters, or dose-rate meters, measure the *dose rate* by recording the number of R being received per hour at the time of measurement. Notice that it takes about seven times as long for the dose rate to decay

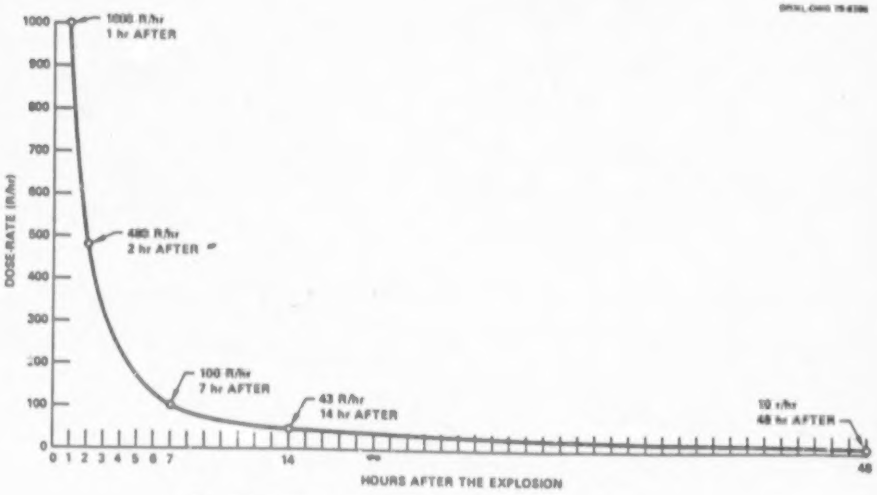


Fig. 1.2. Decay of the dose rate of radiation from fallout.

from 1000 roentgens per hour (1000 R/hr) to 10 R/hr (48 hours) as to decay from 1000 R/hr to 100 R/hr (7 hours). (Only in high-fallout areas would the dose rate 1 hour after the explosion be as high as 1000 roentgens per hour.)

If the dose rate 1 hour after an explosion is 1000 R/hr, it would take about 2 weeks for the dose rate to be reduced to 1 R/hr solely as a result of radioactive decay. Weathering effects will reduce the dose rate further; for example, rain can wash fallout particles from plants and houses to lower positions on or closer to the ground. Surrounding objects would reduce the radiation dose from these low-lying particles.

Figure 1.2 also illustrates the fact that at a typical location where a given amount of fallout from an explosion is deposited later than 1 hour after the explosion, the highest dose rate and the total dose received at that location are less than at a location where the same amount of fallout is deposited 1 hour after the explosion. The longer fallout particles have been airborne before reaching the ground, the less dangerous is their radiation.

Within two weeks after an attack the occupants of most shelters could safely stop using them, or could work outside the shelters for an increasing number of hours each day. Exceptions would be in areas of extremely heavy fallout such as might occur downwind from important targets attacked with many weapons, especially missile sites and very large cities. To know when to come out safely, occupants either would need a reliable fallout meter to measure the changing radiation dangers, or must receive information based on measurements made nearby with a reliable instrument.

The radiation dose that will kill a person varies considerably with different people. A dose of 450 R resulting from exposure of the whole body to fallout radiation is often said to be the dose that will kill about half the persons receiving it, although most studies indicate that it would take somewhat less.[1] *(Note: A number written after a statement refers the reader to a source listed in the Selected References that follow Appendix D.)* Almost all persons confined to expedient shelters after a nuclear attack would be under stress and without clean surroundings or antibiotics to fight infections. Many also would lack adequate water and food. Under these unprecedented conditions, perhaps half the persons who received a whole-body dose of 350 R within a few days would die.[2]

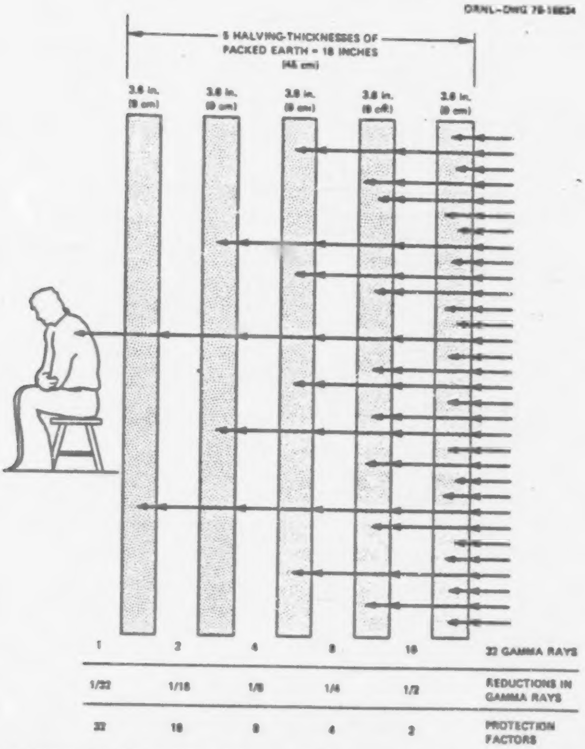
Fortunately, the human body can repair most radiation damage if the daily radiation doses are not too large. As will be explained in Appendix B, a person who is healthy and has not been exposed in the past two weeks to a total radiation dose of more than 100 R can receive a dose of 6 R each day for at least two months without being incapacitated.

Only a very small fraction of Hiroshima and Nagasaki citizens who survived radiation doses—some of which were nearly fatal—have suffered serious delayed effects. The reader should realize that to do essential work after a massive nuclear attack, many survivors must be willing to receive much larger radiation doses than are normally permissible. Otherwise, too many workers would stay inside shelter too much of the time, and work that would be vital to national recovery could not be done. For example, if the great majority of truckers were so fearful of receiving even non-incapacitating radiation doses that they would refuse to transport food, additional millions would die from starvation alone.

- Myth: Fallout radiation penetrates everything; there is no escaping its deadly effects.

- **Facts**: Some gamma radiation from fallout will penetrate the shielding materials of even an excellent shelter and reach its occupants. However, the radiation dose that the occupants of an excellent shelter would receive while inside this shelter can be reduced to a dose smaller than the average American receives during his lifetime from X rays and other radiation exposures normal in America today. The design features of such a shelter include the use of a sufficient thickness of earth or other heavy shielding material. Gamma rays are like X rays, but more penetrating. Figure 1.3 shows how rapidly gamma rays are reduced in number (but not in their ability to penetrate) by layers of packed earth. Each of the layers shown is one halving-thickness of packed earth—about 3.6 inches (9 centimeters).[3] A halving-thickness is the thickness of a material which reduces by half the dose of radiation that passes through it.

The actual paths of gamma rays passing through shielding materials are much more complicated, due to scattering, etc., than are the straight-line paths shown in Fig. 1.3. But when averaged out, the effectiveness of a halving-thickness of any material is approximately as shown. The denser a substance, the better it serves for shielding material. Thus, a halving-thickness of concrete is only about 2.4 inches (6.1 cm).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5 HALVING-THICKNESSES OF PACKED EARTH = 18 INCHES (45 cm)
3.6 in. (9 cm)
3.6 in. (9 cm)
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3.6 in. (9 cm)
3.6 in. (9 cm)
1
2
4
8
16
32 GAMMA RAYS
1/32
1/16
1/8
1/4
1/2
REDUCTIONS IN GAMMA RAYS
32
16
8
4
2
PROTECTION FACTORS

Fig. 1.3. Illustration of shielding against fallout radiation. Note the increasingly large improvements in the attenuation (reduction) factors that are attained as each additional halving-thickness of packed earth is added.

If additional halving-thicknesses of packed earth shielding are successively added to the five thicknesses shown in Fig. 1.3, the protection factor (PF) is successively increased from 32 to 64, to 128, to 256, to 512, to 1024, and so on.

- Myth: A heavy nuclear attack would set practically everything on fire, causing "firestorms" in cities that would exhaust the oxygen in the air. All shelter occupants would be killed by the intense heat.

- Facts: On a clear day, thermal pulses (heat radiation that travels at the speed of light) from an air burst can set fire to easily ignitable materials (such as window curtains, upholstery, dry newspaper, and dry grass) over about as large an area as is damaged by the blast. It can cause second-degree skin burns to exposed people who are as far as ten miles from a one-megaton (1 MT) explosion. (See Fig. 1.4.) (A 1-MT nuclear explosion is one that produces the same amount of energy as does one million tons of TNT.) If the weather is very clear and dry, the area of fire danger could be considerably larger. On a cloudy or smoggy day, however, particles in the air would absorb and scatter much of the heat radiation, and the area endangered by heat radiation from the fireball would be less than the area of severe blast damage.

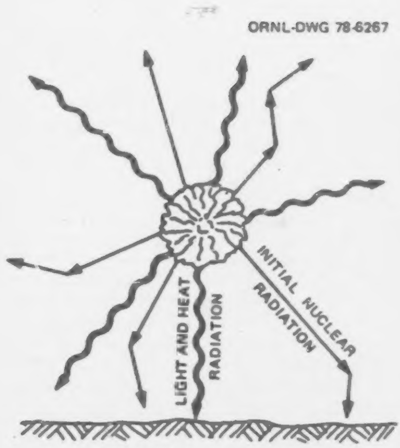

Fig. 1.4. An air burst. The fireball does not touch the ground. No crater, no deadly local fallout. The blast effects, the thermal pulses of intense light and heat radiation, and the very penetrating initial nuclear radiation are the main dangers.

"Firestorms" could occur only when the concentration of combustible structures is very high, as in the very dense centers of a few old American cities. At rural and suburban building densities, most people in earth-covered fallout shelters would have nothing to fear from fire.

- **Myth:** In the worst-hit parts of Hiroshima and Nagasaki where all buildings were demolished, everyone was killed by blast, radiation, or fire.

- **Facts:** In Nagasaki, some people survived uninjured who were far inside tunnel shelters built for conventional air raids and located as close as one-third mile from ground zero (the point directly below the explosion). This was true even though these long, large shelters lacked blast doors and were deep inside the zone within which all buildings were destroyed. (People far inside long, large, open shelters are better protected than are those inside small, open shelters.)

Many earth-covered family shelters were essentially undamaged in areas where blast and fire destroyed all buildings. Figure 1.5 shows a typical earth-covered, backyard family shelter with a crude wooden frame. This shelter was essentially undamaged, although less than 100 yards from ground zero at Nagasaki.[4] The calculated maximum overpressure (pressure above the normal air pressure) was about 65 pounds per square inch (65 psi). Persons inside so small a shelter without a blast door would have been killed by blast pressure at this distance from the explosion. However, in a recent blast test,[5] an earth-covered, expedient Small-Pole Shelter equipped with blast doors was undamaged at 53 psi. The pressure rise inside was slight—not even enough to have damaged occupants' eardrums. If poles are available, field tests have indicated that many families can build such shelters in a few days.

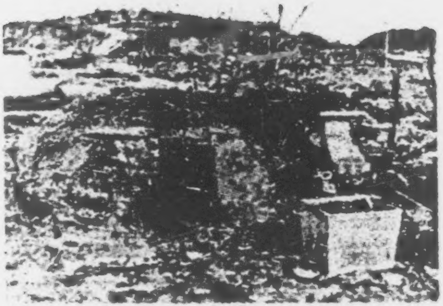

Fig. 1.5. Undamaged earth-covered family shelter in Nagasaki.

The great life-saving potential of blast-protective shelters has been proven in war and confirmed by blast tests and calculations. For example, the area in which the surface-bursting of a 20-megaton weapon would wreck a 50-psi shelter with blast doors is about 17 square miles. Within this roughly circular area, practically all the occupants of wrecked shelters would be killed by blast, carbon monoxide from fires, or radiation. The same blast effects would kill most people who were using basements affording 5 psi protection, over an area of about 186 square miles.[6]

- **Myth:** Because some modern H-bombs are over 1000 times as powerful as the A-bomb that destroyed most of Hiroshima, these H-bombs are 1000 times as deadly and destructive.

- **Facts:** A nuclear weapon 1000 times as powerful as the one that blasted Hiroshima, if exploded under comparable conditions, produces equally serious blast damage to wood-frame houses over an area up to about 130 times as large, not 1000 times as large. However, the blast areas of multimegaton nuclear explosions are impressively large, and Americans concerned with survival should be aware of the destructive power of these huge weapons. For instance, a Soviet SS-9 missile reportedly can deliver a 20-megaton warhead. The explosion from such a weapon would release the same amount of energy as the explosion of 20 million tons of TNT. If a 20-megaton weapon were surface-burst (Fig. 1.1), the great majority of homes at least would be severely damaged to a distance of 10 to 11 miles from ground zero. Within a roughly circular area of about 350 square miles, homes would be severely damaged or completely destroyed.

In and close to the crater area of a large surface burst, even the best blast shelters would be obliterated or buried. In wet, hard rock, a 20-megaton contact surface burst would blast a crater about 550 feet deep. The ringlike, 200-foot-high hill of ejected rock around the crater would be almost a mile across.

If a weapon is air-burst (see Fig. 1.4) at the most advantageous height to produce on the maximum area overpressures that are at least as high as a desired overpressure, it will cover with the desired blast effect an area that is about twice as large as the same weapon would cover if it were surface-burst. A 20-megaton air burst over the center of a great city would cause severe damage to homes as far as 16 miles from ground zero. Nearer to ground zero, the blast damage would be worse. However, the air-bursting of weapons would not result in the often deadly fallout particles that reach the ground within 24 hours after a surface burst. Therefore, for Americans outside target areas, this would be a less dangerous attack than if weapons were surface-burst.

Although some strategists maintain that a limited attack is more probable than a massive one, the author believes it prudent to prepare for the worst possible attack. So let us suppose that an enemy strikes U.S. missile sites and other U.S. military targets with about 40% of its approximately 10,000 megatons of intercontinental nuclear weapons, with another 40% hitting American industries and cities with surface bursts. Most cities would be destroyed by warheads much smaller than 20 megatons. Such a massive attack could subject urban and suburban areas where some 140 million Americans live to blast effects sufficiently intense to destroy essentially all homes. Without well-supplied blast shelters, most urban Americans who would have remained in their cities would be killed by blast, fire, and very heavy fallout. Most Americans would greatly improve their chances of surviving a nuclear attack if they were to evacuate probable target areas before an attack and make or improve fallout shelters in dispersed locations outside these most threatened areas.

- **Myth:** So much food and water will be poisoned by fallout that people will starve and die even in fallout areas where there is enough food and water.

- **Facts:** If the fallout particles do not become mixed with the parts of food that are eaten, no harm is done. Food and water in dust-tight containers are not contaminated by fallout radiation. Peeling fruits and vegetables removes essentially all fallout, as does removing the uppermost several inches of stored grain onto which fallout particles have fallen. Water from many sources—such as deep wells and covered reservoirs, tanks, and containers—would not be contaminated. Even water containing dissolved radioactive elements and compounds can be made safe for drinking by simply filtering it through earth, as described later in this book.

- **Myth:** Most of the unborn children and grandchildren of people who have been exposed to radiation from nuclear explosions will be genetically damaged—will be malformed, delayed victims of nuclear war.

- **Facts:** The authoritative study by the National Academy of Sciences, *A Thirty Year Study of the Survivors of Hiroshima and Nagasaki*, was published in 1977. It concludes that the incidence of abnormalities is no higher among children later conceived by parents who were exposed to radiation during the attacks on Hiroshima and Nagasaki than is the incidence of abnormalities among Japanese children born to unexposed parents.

This is not to say that there would be no genetic damage, nor that some fetuses subjected to large radiation doses would not be damaged. But the overwhelming evidence does show that the exaggerated fears of radiation damage to future generations are not supported by scientific findings.

- **Myth:** Overkill would result if all the U.S. and U.S.S.R. nuclear weapons were used—meaning not only that the two superpowers have more than enough weapons to kill all of each other's people, but also that they have enough weapons to exterminate the human race.

11

● **Facts:** Statements that the U.S. and the Soviet Union have the power to kill the world's population several times over are based on misleading calculations. One such calculation is to multiply the deaths produced per kiloton exploded over Hiroshima or Nagasaki by an estimate of the number of kilotons in either side's arsenal. (A kiloton explosion is one that produces the same amount of energy as does 1000 tons of TNT.) The unstated assumption is that somehow the world's population could be gathered into circular crowds, each a few miles in diameter with a population density equal to downtown Hiroshima or Nagasaki, and then a small (Hiroshima-sized) weapon would be exploded over the center of each crowd. Other misleading calculations are based on exaggerations of the dangers from long-lasting radiation and other harmful effects of a nuclear war.

In conclusion, we view the problem in determining the consequences of large scale nuclear war to be much the same as the problem which H. Jack Geiger wrote of in an article entitled, "The illusion of survival" which appeared in the June/July, 1981 issue of The Bulletin of the Atomic Scientists:

> On the one hand, the nature and magnitude of the effects of hypothetical—but eminently possible—nuclear attacks are entirely specifiable. The calculations are straightforward and only moderately complex. Indeed, over the past two decades, these consequences have been described in exquisite detail in hundreds of scientific journals, books and government publications.
>
> On the other hand, despite the specificity, these effects—the numbers of killed and injured, the destruction of the physical environment, the damage to the ecosphere—are unfathomable. In short, it is almost impossible fully to grasp the reality they represent, the implications they carry.

Appendix to Dissenting Views

The Effects of Nuclear War

CONGRESS OF
THE UNITED STATES
Office of Technology Assessment
WASHINGTON D. C. 20510

APPENDIX E—SUGGESTIONS FOR FURTHER READING

Physical Effects of Nuclear Warfare

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